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WEEKDAY/WEEKEND OZONE OBSERVATIONS IN THE SOUTH COAST AIR BASIN VOLUME III: ANALYSIS OF SUMMER 2000 FIELD MEASUREMENTS AND SUPPORTING DATA

FINAL REPORT
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PREFACE

The Desert Research Institute (DRI) and Sonoma Technology, Inc. (STI) conducted a study of the causes of elevated ozone levels on weekends in the South Coast (Los Angeles) Air Basin (SoCAB). This work was conducted over a period of 30 months beginning in December 1999. In the initial phase of the study, DRI examined the spatial, temporal, and statistical distributions of ozone, carbon monoxide, total non-methane hydrocarbons, and nitrogen oxides for routine monitoring sites in the SoCAB with continuous data from 1981 to 1998. STI reviewed available activity data for VOC and NOx emissions and investigated important meteorological phenomena in the SoCAB in the context of day-of-week variations. The results and findings from these retrospective analyses are summarized in the following three volumes:

- Fujita E.M., Stockwell W., Keislar R.E., Campbell D.E., Roberts P.T., Funk T.H., MacDonald C.P., Main H.H., and Chinkin LR. (2000a) Weekend/weekday ozone observations in the South Coast Air Basin: Retrospective analysis of ambient and emissions data and refinement of hypotheses, Volume I – Executive Summary. Final report prepared for the National Renewable Energy Laboratory, Golden, CO, by the Desert Research Institute, Reno, NV and Sonoma Technology, Petaluma, CA, December.

- Fujita E.M., Stockwell W., Keislar R.E., and Campbell D.E. (2000b) Weekend/weekday ozone observations in the South Coast Air Basin: Retrospective analysis of ambient and emissions data and refinement of hypotheses, Volume II – Desert Research Institute Tasks 1 and 2. Prepared for the National Renewable Energy Laboratory, Golden, CO by the Desert Research Institute, Reno, NV, December.

- Roberts P.T., Funk T. H., MacDonald C.P., Main H.H., and Chinkin L.R. (2001) Weekend/weekday ozone observations in the South Coast Air Basin: Retrospective analysis of ambient and emissions data and refinement of hypotheses, Volume III – Final report prepared for the National Renewable Energy Laboratory, Golden, CO by Sonoma Technology, Inc., Petaluma, CA, January.

In the second phase of the study, a field measurement program was conducted in September-October 2000 to collect and assemble air quality and emission activity databases to examine relationships between emission patterns and key air quality parameters relevant to the weekend ozone effect. The following interim report presents preliminary results from the field study and describes the applicable measurement methods and approaches for data analysis:

- Fujita E.M., Campbell D.E., Stockwell W., Zielinska B., Sagebiel J.C., Goliff W., Keith M., and Bowen J.L. (2001) Weekend/weekday ozone observations in the South Coast Air Basin: Phase II field study. Interim report prepared for the National Renewable Energy Laboratory, Golden, CO, by the Desert Research Institute, Reno, NV, November.

The final report of this study consists of the three volumes referenced below. The Executive Summary (Volume I) provides a synthesis of the results obtained by DRI and STI with respect to a variety of hypotheses for the weekend ozone effect. Volume II documents the results obtained by DRI from the Phase II field study. It also summarizes the retrospective analyses performed during Phase I and additional analyses that were conducted by DRI to update the findings from Phase I. Volume III is a summary of STI's analysis of the prevailing meteorology during the Phase II field study and the collection of emission activity data in support of this study. Volume III also includes a discussion of weekday/weekend differences in hydrocarbons.

- Fujita E.M., Campbell D.E., Stockwell W., Roberts P.T., Funk T.H., MacDonald C.P., Main H.H., and Chinkin L.R. (2002) Weekend/weekday ozone observations in the South Coast Air Basin Volume I – Executive Summary. Report prepared for the National Renewable Energy Laboratory, Golden, CO, and the Coordinating Research Council by the Desert Research Institute, Reno, NV and Sonoma Technology, Petaluma, CA, May.

- Fujita E.M., Campbell D.E., Stockwell W., Keislar R., Zielinska B., Sagebiel J.C., Goliff W., Keith M., and Bowen J.L. (2002) Weekend/weekday ozone observations in the South Coast Air Basin Volume II: Analysis of air quality data. Final report prepared for the National Renewable Energy Laboratory, Golden, CO, and the Coordinating Research Council by the Desert Research Institute, Reno, NV, April.

- Chinkin L.R., Main H.H., and Roberts. P.T. (2002) Weekend/weekday ozone observations in the South Coast Air Basin Volume III: Analysis of summer 2000 field measurements and supporting data. Final report prepared for the National Renewable Energy Laboratory, Golden, CO by Sonoma Technology, Inc., Petaluma, CA, April.

ACKNOWLEDGMENTS

The authors thank the U.S. Department of Energy's Office of Heavy Vehicle Technologies for financial support of this project, which was funded through the National Renewable Energy Laboratory. The authors also thank Dr. Douglas Lawson for his guidance on this investigation of the weekday/weekend differences in ozone in the SoCAB. We worked closely with Dr. Eric Fujita at Desert Research Institute on this project; his input (and written contributions, such as the preface for this report) has been invaluable.

A number of STI analysts contributed to the planning, analysis, presentation, and documentation of the scientific findings presented in the final report:

- Ms. Dana Coe and Ms. Tami Funk performed the analysis of the emissions activity data presented in Section 2. Ms. Coe coordinated the emission activity data collection efforts.
- Dr. Pat Ryan contributed significantly to the preparation of Section 2 documentation.
- Ms. Patricia Stiefer analyzed the emissions activity data from point sources, also presented in Section 2.
- Mr. Clinton MacDonald and Mr. Charley Knoderer performed the meteorological analyses presented in Section 3. Mr. MacDonald also served as the task manager for the meteorological analysis task.
- Ms. Carryl Hardy and Ms. Jun Wu provided data processing support for the hydrocarbon data analyses presented in Section 4.

STI staff worked with two consulting firms to obtain emissions activity information. The authors thank staff at the following firms for their data collection efforts:

- Freeman, Sullivan & Co., who conducted residential and business surveys.
- Wiltech, who obtained surface street traffic volume counts.

Finally, we worked with the following people and organizations to obtain emissions activity data; their contributions are greatly appreciated:

- Bob Effa, John Nguyen, Cheryl Taylor, Dale Shimp, Larry Larsen, John Taylor, Mena Shah, and Mark Carlock at the California Air Resources Board
- Vahid Nowshiravan at Caltrans
- Dr. Deb Niemeier at the University of California at Davis
- Chris Marlia at the South Coast Air Quality Management District

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GLOSSARY

AIRS	Aerometric Information Retrieval System
AQ	air quality
ARL	Air Resources Laboratory
CARB	California Air Resources Board
CEM	continuous emissions measurement
CO	carbon monoxide
DOW	day of week
DRI	Desert Research Institute
EPA	U.S. Environmental Protection Agency
HONO	nitrous acid
HCHO	formaldehyde
HD	heavy-duty
HDV	heavy-duty vehicle
IC	internal combustion
LD	light-duty
LDV	light-duty vehicle
MSA	metropolitan statistical areas
NARSTO	North American Research Strategy for Tropospheric Ozone
NO	nitric oxide
NOAA	National Oceanic and Atmospheric Administration
NO_x	oxides of nitrogen defined as NO + NO_2 + poorly defined fraction of other NO_y species (given conventional analyzers)
NO_y	oxides of nitrogen defined as NO + NO_2 + HNO_3 (nitric acid) + organic nitrates + inorganic nitrates
PAMS	Photochemical Assessment Monitoring Stations
PAN	peroxyacetyl nitrate
PM	particulate matter
PM_{10}	particulate matter less than 10 microns
PST	Pacific Standard Time
ROG	reactive organic compounds
SoCAB	Southern California Air Basin
SCAQMD	Southern California Air Quality Management District
SCOS97	1997 Southern California Ozone Study
STI	Sonoma Technology, Inc.
TNMOC	total nonmethane organic compound
TPD	tons per day
VOC	volatile organic compound
WD	weekday
WE	weekend
WIM	weigh-in-motion

1. INTRODUCTION

Sonoma Technology, Inc. (STI) and the Desert Research Institute (DRI) conducted a study of the causes of elevated ozone levels on weekends in the South Coast (Los Angeles) Air Basin (SoCAB). The project consisted of three phases (each including several tasks) conducted over a period of 30 months, beginning in November 1999. Specific objectives of Phase I were (1) to acquire emissions activity, meteorological, and air quality data in order to establish data needs and priorities for a Phase II field study data acquisition and measurements program and (2) to refine hypotheses for further testing in Phases II and III. A field measurement program, collection of emission activity data, and the assembly of air quality, emissions, and meteorological data required to help verify or disprove our weekend effect hypotheses was conducted in Phase II. In Phase III, we analyzed all data collected under Phases I and II. This report documents STI's findings. DRI is documenting their Phase III findings separately.

1.1 BACKGROUND AND OBJECTIVES

Since the mid-1970s, and possibly earlier, ozone concentrations in California's SoCAB have been higher on weekends than on weekdays, and this tendency has been more pronounced in the western SoCAB. This occurs despite assumed lower emissions on weekends than on weekdays. The weekend effect has generated strong interest because of its potential implications on ozone control strategies. Much of the difficulty in addressing the ozone problem is related to ozone's complex photochemistry in which the rate of ozone production is a non-linear function of the mixture of volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the atmosphere. Depending upon the relative concentrations of VOCs and NO_x and the specific mix of VOCs present, the rate of ozone formation can be most sensitive to changes in VOCs alone, to changes in NO_x alone, or to simultaneous changes in both VOCs and NO_x. Understanding the response of ozone concentrations to specific changes in VOCs or NO_x emissions is a fundamental prerequisite to developing less costly and more effective ozone abatement strategies.

Results of previous studies in the SoCAB indicate that, in general, air quality on weekends is significantly different from weekdays, and this difference is not due to weather phenomena. Therefore, it has been postulated that the observed weekend effect in the SoCAB arises from day-of-week variations in the temporal and spatial patterns of VOCs and NO_x emissions, coupled with the complex interactions of physical and chemical processes.

1.2 HYPOTHESES FOR THE WEEKEND OZONE EFFECT

At the beginning of this project, DRI and STI formulated hypotheses to explain the day-of-week differences in ozone concentrations. The Phase I analyses and Phase II data collection activities were designed to address the hypotheses. The hypotheses are related to (1) the interactions of ambient concentrations of VOCs and NO_x, chemical transformations, and transport that affect the day-of-week differences in the diurnal evolution of ozone chemistry, and (2) emission-activity differences between weekdays and weekends that affect the photochemistry.

The seven hypotheses are categorized into three types of changes: ozone inhibition, ozone formation rates, and day-of-week photolysis rates. Under each of the seven hypotheses described below, emission hypotheses that are the presumed cause of the air quality effect are identified (by small letters).

Some of the terms used in the following hypotheses were defined in Phase I. Fujita et al. (2001 – Phase I report) summarized the four phases of the diurnal ozone cycle:

- Ozone carryover - overnight, the nocturnal boundary layer contains pollutants from the previous day (carryover) as well as fresh emissions. Ozone concentrations are generally low during the night and early morning as fresh nitric oxide (NO) titrates the ozone.
- Ozone inhibition - in the early morning, ozone formation is inhibited due to titration with NO. The time in the morning when NO and ozone concentrations "cross over" (i.e., ozone concentrations become higher than NO concentrations) is defined as the end of the inhibition period and the beginning of ozone production via conversion of NO to NO_2 by peroxy radical.
- Ozone accumulation - the period extending from the end of the inhibition period to the time of maximum ozone concentration.
- Post-ozone maximum - is characterized by increased vertical mixing and horizontal advection, declining actinic flux, and titration of ozone by fresh NO emissions during the afternoon.

<u>Hypotheses related to changes in ozone inhibition on weekends</u>

1. Lower NO concentrations on weekend mornings result in decreased ozone inhibition, and therefore higher initial ozone concentrations, on weekend mornings compared to weekday mornings.
    a. Heavy-duty diesel truck (and bus, train) activity is less on weekends during the ozone inhibition period than on weekdays, resulting in lower NO concentrations and less ozone inhibition on weekends.
    b. On-road light-duty gasoline vehicular activity is less on weekends during the ozone inhibition period than on weekdays, resulting in lower NO concentrations and less ozone inhibition on weekends.

<u>Hypotheses related to changes in ozone formation rates due to changes in the VOC/NO_x ratio or other factors</u>

2. Lower NO concentrations on weekend mornings result in higher VOC/NO_x ratios than on weekday mornings.
    a. Heavy-duty diesel truck (and bus, train) activity is less on weekends during the ozone accumulation period than on weekdays resulting in higher VOC/NO_x ratios and higher ozone formation rates on weekends.
    b. On-road light-duty gasoline vehicular activity on weekends is similar to or higher than on weekdays during the ozone accumulation period. Lower diesel NO_x emissions during the same period results in higher weekend VOC/NO_x ratios during this period.

3. Higher VOC concentrations on weekend mornings result in higher VOC/NO_x ratios than on weekday mornings.
    a. Use of off-road recreational vehicles, lawn and garden equipment, backyard barbecues, and household solvents is higher on weekends than on weekdays resulting in higher weekend VOC/NO_x ratios.
4. Greater carryover of VOC concentrations relative to NO_x concentrations on Friday and Saturday evenings results in higher VOC/NO_x ratios and an increased rate of ozone formation on weekend mornings.
    a. Heavy-duty diesel activity is lower on Friday and Saturday evenings than on other evenings resulting in overnight carryover of pollutants with higher VOC/NO_x ratios.
    b. Light-duty gasoline vehicle traffic is higher while heavy-duty diesel traffic is lower on Friday and Saturday evenings than on other evenings resulting in overnight carryover of pollutants with higher VOC/NO_x ratios.
5. Ozone, VOCs, and NO_x-sensitive air parcels from aloft combined with lower NO_x emissions at the surface on weekend mornings results in more efficient ozone production during the ozone accumulation period on weekends.
6. Because ozone inhibition is lower on weekends, nitrous acid (HONO), formaldehyde (HCHO), peroxyacetyl nitrate (PAN), or other early-morning radical sources increase in relative importance. These radical sources may be contained in the surface or aloft carryover.

<u>Hypotheses related to higher photolysis rates on weekends</u>

7. Lower particulate matter (PM) concentrations on weekends increase the direct and scattered ultraviolet radiation available for photolysis, thus increasing the rate of ozone formation compared to weekdays.
    a. Less vehicle traffic on weekends, especially heavy-duty diesel truck (and bus, train), results in lower direct emissions of soot particles that absorb light.
    b. Less vehicle traffic on weekends, especially heavy-duty diesel truck (and bus, train), results in lower emissions of NO_x that react to form secondary nitrate particles.

This report describes STI's findings on the emissions-activity differences that affect ozone. DRI will report separately, its findings based on ambient air quality data.

1.3 GUIDE TO REPORTS

1.3.1 Description of Project Reports

Phase I reports

STI's Phase I report (Roberts et al., 2001) summarizes available emissions data, based on literature reviews and discussions with several government agencies and industry experts. We also examine historical ozone events and assess key meteorological parameters and their association with high ozone concentrations. Using three-dimensional ozone and meteorological data from the 1997 Southern California Ozone Study-North American Research Strategy for Tropospheric Ozone (SCOS97-NARSTO) study, this report identifies variations in ozone concentrations attributable to day-to-day variations in meteorology rather than day-to-day (or weekday-to-weekend) variations in emissions. Therefore, one must account for the effects of meteorology in analyses that compare weekend and weekday episodes. Winds and mixing heights are two meteorological parameters that exhibit a strong day-to-day influence on ozone concentrations.

DRI's Phase I report (Fujita et al., 2000a) examines the spatial, temporal, and statistical distributions of ozone, carbon monoxide, total non-methane hydrocarbons and nitrogen oxides for routine monitoring sites in the SoCAB with continuous data from 1981 to 1998.

STI and DRI collaboratively prepared an executive summary of the Phase I analyses performed by both contractors (Fujita et al., 2000b).

Phase II reports

During Phase II of the project, STI compiled data for use in Phase III assessments of possible weekend effects. Data collected included traffic data on surface streets and freeways and patterns of emissions-related activities at commercial and residential locations near ambient monitors. STI 's Phase II activities are documented in this Phase III report.

In Phase II, DRI conducted a field measurement program from September 29 to October 9, 2000 to collect data and assemble an air quality database. Combined with the emission activity data collected by STI, the data were used to examine relationships between emission patterns and key air quality parameters relevant to the weekend ozone effect. DRI's Phase II activities are documented in their Phase III report.

Phase III reports

A collaborative synthesis of findings will be prepared from STI's and DRI's separate Phase III reports. The synthesis report will include a discussion of the overall conclusions of the study. Findings will be ranked by degree of confidence as they relate to the emissions-activity and ozone chemistry hypotheses. The report will also provide implications towards ozone control strategies as well as recommendations for further measurements and analyses.

1.3.2 Guide to This Report

This report describes the results from the analysis of the weekday and weekend emission activity data and the analysis of air quality and meteorological data on the days of the fall 2000 field study. Summaries of the collection of emission activity data and the assembly of air quality, emissions, and meteorological data required to help verify or disprove weekend effect hypotheses conducted in Phase II are provided as appendices in this Phase III report. Section 2 provides a description of the methods and results of emissions activity data collected or compiled in this study. Section 3 provides an overview of the meteorology during the field study period of the study as well as meteorology during the SCOS97 episode. Section 4 presents the air quality analyses performed to better understand day-of-week differences in ozone precursors in the SoCAB. Section 5 provides conclusions and recommendations from STI's analyses. Section 6 lists references cited in the report.

2. EMISSIONS ACTIVITY BY DAY OF WEEK

A number of hypotheses put forth to explain higher ozone concentrations on weekends in the South Coast Air Basin are based on the possibility of emissions activity differences between weekdays (WDs) and weekends (WEs). The hypothesized differences in WD/WE activity are assumed to affect emission rates, which affect photochemistry and accumulation of ozone. Everyday observations and common sense suggest that aggregate variations in human activities, which follow a WD/WE pattern, likely cause observable differences in WD/WE air quality. This section describes the data collection efforts and results to obtain real-world estimates of the activity variations by day-of-week for major emissions source categories in the SoCAB. Further details of the methods and results are provided in Appendices A through I.

2.1 BACKGROUND

The SoCAB covers an area of approximately 6,500 square miles and has a population of more than 14 million. The California Air Resources Board (CARB) and the South Coast Air Quality Management District (SCAQMD) routinely publish emission inventories for the SoCAB. Summer daily average 2000 emissions of reactive organic compounds (ROG), nitrogen oxides (NO_x), carbon monoxide (CO), and particulate matter less than 10 microns (PM_{10}) are shown in **Tables 2-1 and 2-2** (California Air Resources Board, 2001). Table 2-1 lists total emissions by source category (stationary and area, on-road mobile, and other mobile), pollutant, and subcategory (e.g., gasoline and diesel vehicles). On-road mobile source emissions estimates in Tables 2-1 and 2-2 are from EMFAC2000 Version 2.02.

Table 2-2 shows that on-road mobile sources are the single largest source category for ozone precursor pollutants, accounting for 49%, 62%, and 80% of average daily ROG, NO_x, and CO, respectively, in the SoCAB. Most of the on-road emissions are due to gasoline vehicles, but diesel vehicles contribute substantially to NO_x emissions. Second to on-road mobile sources, stationary and area-wide sources are significant sources of ROG, while other mobile sources are a less important source of ROG. In contrast, other mobile sources generate relatively large emissions of NO_x, while stationary and area-wide sources are less important NO_x contributors. The majority of CO emissions are associated with on-road and other mobile sources. While CO emissions are not a major contributor to ozone formation, CO may serve as a tracer for mobile source emissions since CO is primarily associated with mobile source fuel combustion. **Figures 2-1 and 2-2** display the source category contributions to total ROG and NO_x emissions, respectively.

Table 2-1. Estimated average summertime emissions for 2000 in the SoCAB (tons/day).

Source Category	ROG	NO_x	CO	PM_{10}
Stationary and Area Sources				
Fuel Combustion	11.6	87.3	42.7	7.8
Waste Disposal	2.6	1.9	0.9	0.4
Cleaning & Surface Coatings (Industrial)	137.1	0.0	0.0	0.1
Petroleum Production & Marketing	36.6	4.1	4.8	1.3
Industrial Processes	22.5	10.5	5.8	13.0
Solvent Evaporation (Consumer)	182.1	0.0	0.0	0.0
Misc. Processes (Residential Fuel Combustion, Road Dust)	16.4	24.3	82.8	283.9
Total, Stationary and Area Sources	**408.9**	**128.1**	**137.0**	**306.5**
On-Road Mobile Sources				
Passenger Cars	323.0	247.0	2990.0	9.0
Light- & Medium-Duty Trucks	160.0	192.0	1896.0	8.0
Light-, Medium-, & Heavy-Duty Trucks (Gasoline)	46.0	56.0	622.0	6.3
Light-, Medium-, & Heavy-Duty Trucks (Diesel)	12.5	227.0	62.3	8.1
Other On-Road Mobile	10.3	1.4	106.0	2.4
Source Category	ROG	NO_x	CO	PM_{10}
Other Mobile Sources (Off-road equipment)	154.6	313.4	1250.3	19.9
Total, On- and Off-road Mobile Sources	**706.4**	**1036.8**	**6926.6**	**53.7**
Total (all anthropotenic categories)	**1115.3**	**1164.9**	**7063.6**	**360.2**
Total (all biogenic categories)[1]	**125.0**	**–**	**–**	**–**

[1] Note that current estimates of biogenic hydrocarbon emissions are uncertain. Benjamin et al. (1997) estimate present biogenic hydrocarbon emissions of 125 to 200 TPD. However, "[S]ince the majority of the biogenic hydrocarbon emissions occur in the mountains located on the northern and eastern boundaries of the SoCAB, downwind of the most heavily populated areas, the actual impact of these emissions on air quality is probably less than is suggested by the magnitude of the inventory, even after taking into account the higher reactivity of the vegetative hydrocarbons."

Source of table: CARB web site: http://www.arb.ca.gov/app/emsinv/fcemssumcat.html

Table 2-2. Estimated average daily emissions by major source category for summer 2000 in the SoCAB (percent of total).

Source Category	ROG	NO_x	CO	PM_{10}
Stationary & Area-Wide	37	11	2	85
On-road Mobile	49	62	80	9
Other Mobile	14	27	18	6

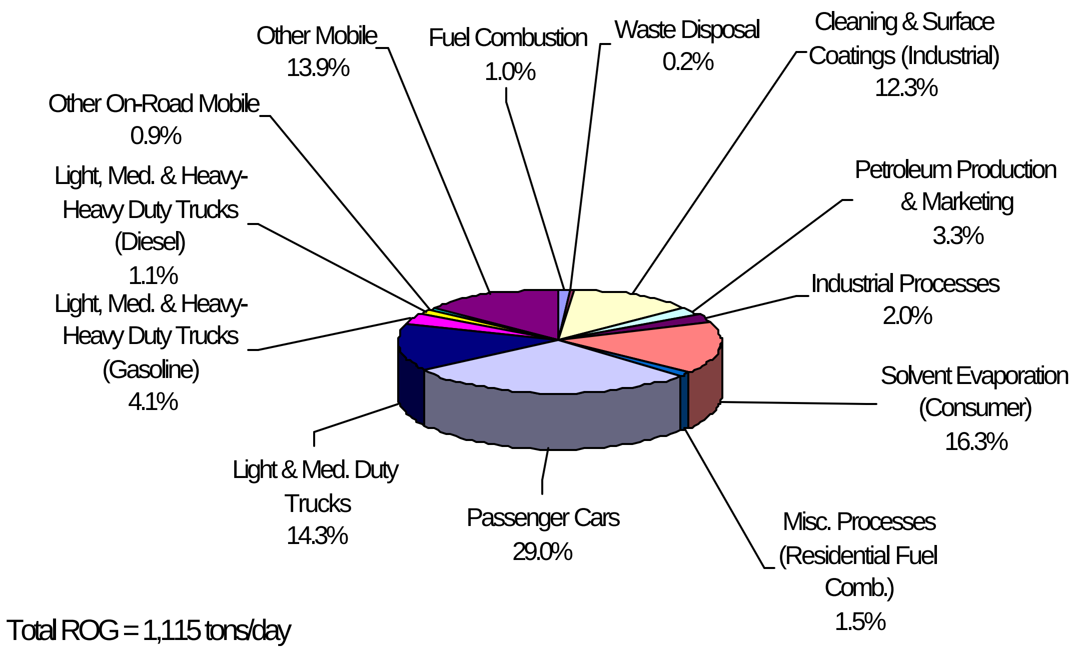


Figure 2-1. Emission source category contributions to total ROG emissions in the SoCAB in 2000. Mobile source emissions estimates are based on EMFAC2000 Version 2.02.

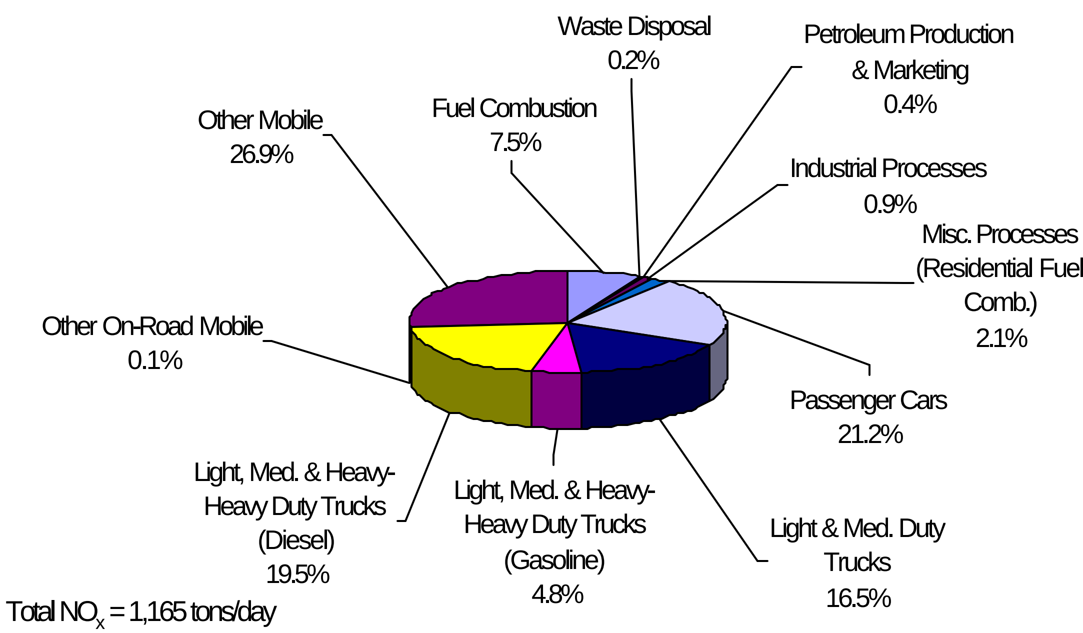


Figure 2-2. Emission source category contributions to total NO_x emissions in the SoCAB in 2000. Mobile source emissions estimates are based on EMFAC2000 Version 2.02.

2.2 TECHNICAL APPROACH

To investigate the differences between weekday and weekend anthropogenic emissions patterns, anthropogenic emissions sources that are likely to show significant variations between weekdays and weekends were identified. Once the key source categories were identified, a data collection effort was undertaken to acquire relevant weekday and weekend activity data for those categories. Specifically, new emissions activity data were collected for on-road mobile sources, lawn and garden equipment sources, selected area-wide sources, and major point sources in the SoCAB. Surveys of land use and emissions source types near selected air quality monitoring sites were also conducted (see Appendix C for resulting land use and emissions source type maps).

This section describes the methods used to collect emissions activity data for on-road mobile sources, area-wide sources, major point sources, and off-road lawn and garden equipment sources in the SoCAB. The collected data were used to estimate emission differences by day of week as shown in the next section. Different data collection techniques were implemented to address the unique nature of the activities associated with the different source categories as described below:

<u>On-Road Mobile Sources</u>

- Weigh-in-motion (WIM) freeway traffic volume information was acquired from the California Department of Transportation (Caltrans) in cooperation with the CARB for a number of sites in the SoCAB for one full year (2000).
- Surface street traffic volume information was collected on local streets at selected locations near air quality monitoring sites during the 10-day field study in September and October 2000.

<u>Stationary and Area Sources</u>

- Survey questionnaires were developed to obtain activity information from a sample of businesses and residences by day-of-week and time-of-day. See Appendix A for survey details.
- Continuous emissions measurement (CEM) NO_x data from major point sources were acquired on a 24-hour day-of-week basis for two summers (1997 and 2000).

<u>Off-Road Mobile Equipment</u>

- Survey questionnaires were developed to obtain activity information by day-of-week and time-of-day from a sample of lawn and garden businesses and institutional users (e.g., golf courses, parks, and schools). See Appendices B and D for survey details.

2.2.1 Selected Sites in the SoCAB

Freeway, point source, and lawn and garden emissions-related activity information for this study was collected throughout the SoCAB. Emissions-related activity data collected from small business and residential surveys and surface street traffic volumes were geographically focused on the neighborhoods surrounding selected ambient air quality monitoring sites in the SoCAB. The selected sites (e.g., Azusa, Pico Rivera, L.A. North Main, and Industry Hills) are depicted in **Figure 2-3**. Unique sources of emissions within 5 km of each site were identified, including residential areas, commercial and industrial parks, stadiums, and recreation areas that may have different impacts on ambient measurements on weekdays and weekends. Detailed site maps are provided in Appendix C.

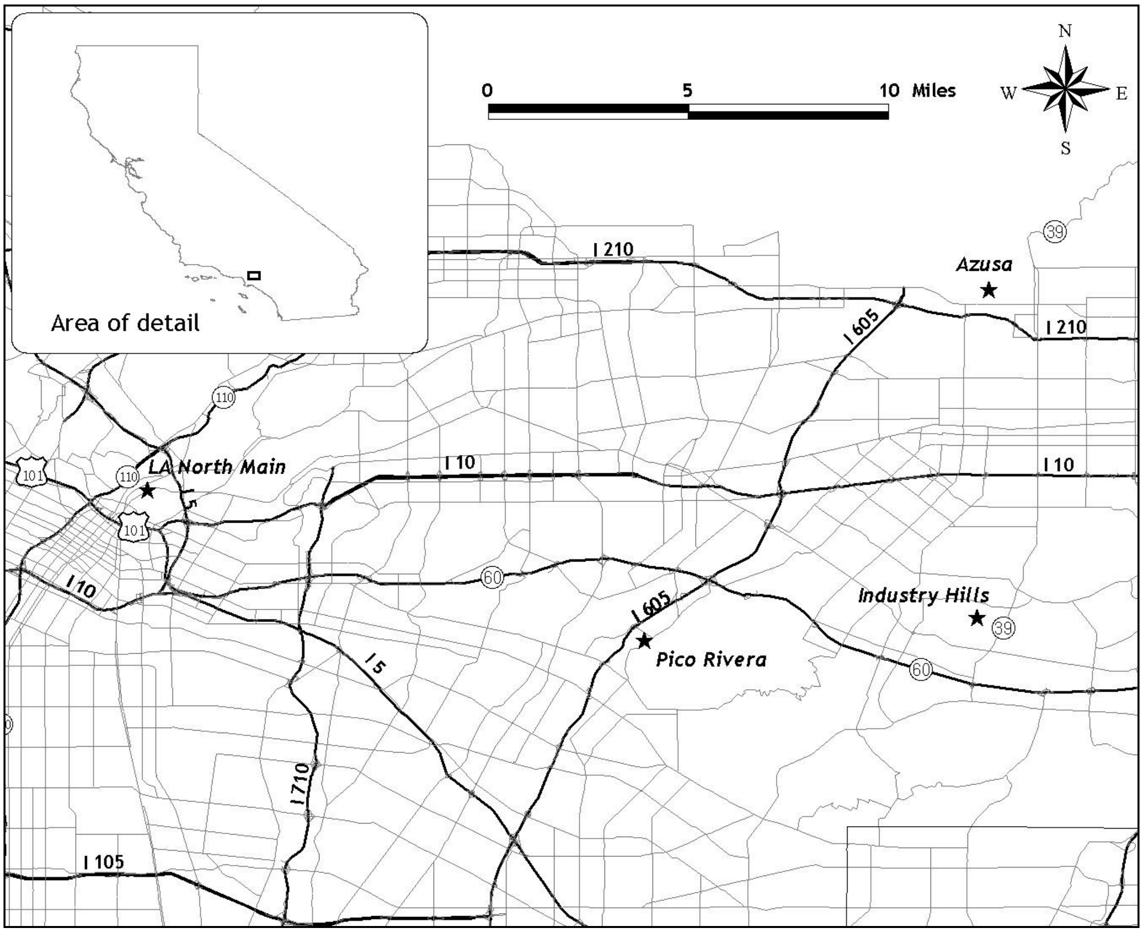


Figure 2-3. Locations of monitoring sites used as focus of data collection within the SoCAB.

2.2.2 On-road Mobile Sources

Traffic volumes were monitored on surface streets with automated pneumatic devices (loop sensors) that detect tire passages. Single loop sensors provide vehicle counts only. If two loop sensors are placed in a traffic lane with a known distance between them, they may be used to disaggregate traffic volumes by vehicle type. The vehicle typing is performed via an algorithm that processes time intervals between tire passages, and from these time intervals the algorithm predicts the number of axles, axle spacing, and vehicle type. The algorithm is associated with potentially high vehicle misclassification errors (much more so than WIM sites);

however, these errors tend to cancel out when relative vehicle type counts are considered (e.g., number of trucks per day divided by the number of trucks per week).

Loop sensors were deployed on 10 surface streets at various locations around the interior basin and were operated continuously for a period of 9 to 12 days beginning on Friday, September 29, 2000. Of the 10 sites, four received arrays of loop sensors for vehicle-type counts. The loop sensors were visited at least daily for maintenance—this was particularly important for streets with heavy traffic—because the adhesive that holds them onto the street surface tends to break down over time. Traffic data were collected from arterial and collector streets (listed below). An arterial is a roadway that serves major traffic movements and, secondarily, provides access to abutting land (precise definitions vary among localities and states). A collector is an urban street which provides access within neighborhoods, commercial, and industrial districts and which channels traffic from local streets to minor and major arterials (Harvey and Deakin, 1993). Additional traffic data were collected from a residential street and a recreational location. Sites that received vehicle-type sensor arrays are indicated in the following list with an asterisk.

<u>Arterial Streets</u>

- Azusa Avenue south of Industry Hills Parkway*, which was nearly collocated with Azusa Avenue north of Temple Avenue (La Puente, California)
- San Gabriel River Parkway north of Beverly Boulevard (Pico Rivera, California)*
- Vignes Street east of Main Street (downtown Los Angeles, California)
- Beverly Boulevard west of San Gabriel River Road (Pico Rivera, California)
- Foothill Boulevard east of Todd Avenue*, which was collocated with Foothill Boulevard west of Todd Avenue (Azusa, California)

<u>Collectors</u>

- 800 North Main Street* (Los Angeles, California)
- Main Street west of Azusa Avenue (La Puente, California)
- West Sierra Madre Avenue east of Todd Avenue (Azusa, California)

Traffic volume data for freeways were acquired for Caltrans WIM sites. The WIM network consists of sensors embedded in freeways that instantaneously record the number, weight, and speed of passing vehicles. The data are binned by 14 vehicle classes based on vehicle weight and axle spacing. For most WIM sites, data are collected for all lanes of traffic and in both directions. The standard Caltrans protocol for processing WIM data is to summarize, quality assure, and archive two weeks of data per month for every site. For this study, data from 1997 and 2000 were acquired through a collaborative effort with the CARB and Caltrans. **Figure 2-4** shows the WIM site locations in the SoCAB for which data were analyzed. (Note that approximately 20 WIM sites currently exist in Southern California. However, only 9 sites with sufficiently complete data for year 2000 were used in this analysis.) WIM sites were classified into two groups, interior basin and inflow/outflow, based on characteristics of the observed traffic patterns and geography. The groups were differentiated by day-of-week and diurnal traffic patterns:

- Two inflow/outflow sites are located along major freeways, Indio on Interstate 10 and Castaic on Interstate 5, which are corridors to and from the SoCAB.

- Six interior basin sites are scattered throughout the central urban zone of the SoCAB.
- The Long Beach WIM data were treated individually because the sensor was located on the access route to the very busy Port of Long Beach.

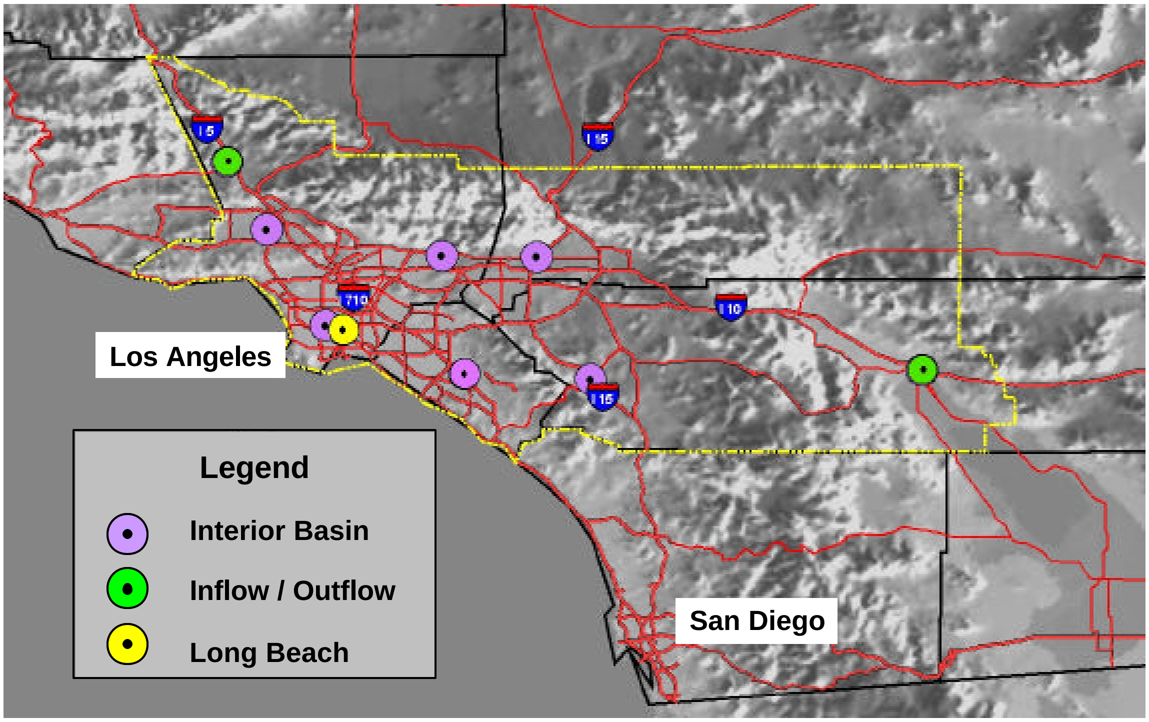


Figure 2-4. Locations of Caltrans weigh-in-motion (WIM) sensors analyzed for this study.

2.2.3 Stationary and Area Sources

We obtained NO_x CEM data collected in the SoCAB from the SCAQMD for June through August of 1999 and 2000. **Figure 2-5** depicts the locations of these point sources. These emissions data were reported by day of week. Data for these sources were analyzed to characterize WD/WE differences in point source emissions. Total NO_x emissions (about 50 tons per day, on average) from the point sources reporting CEM data represent about 75% of total point source NO_x emissions in the SoCAB and comprise approximately 50% of the summertime total stationary and area source NO_x emissions.

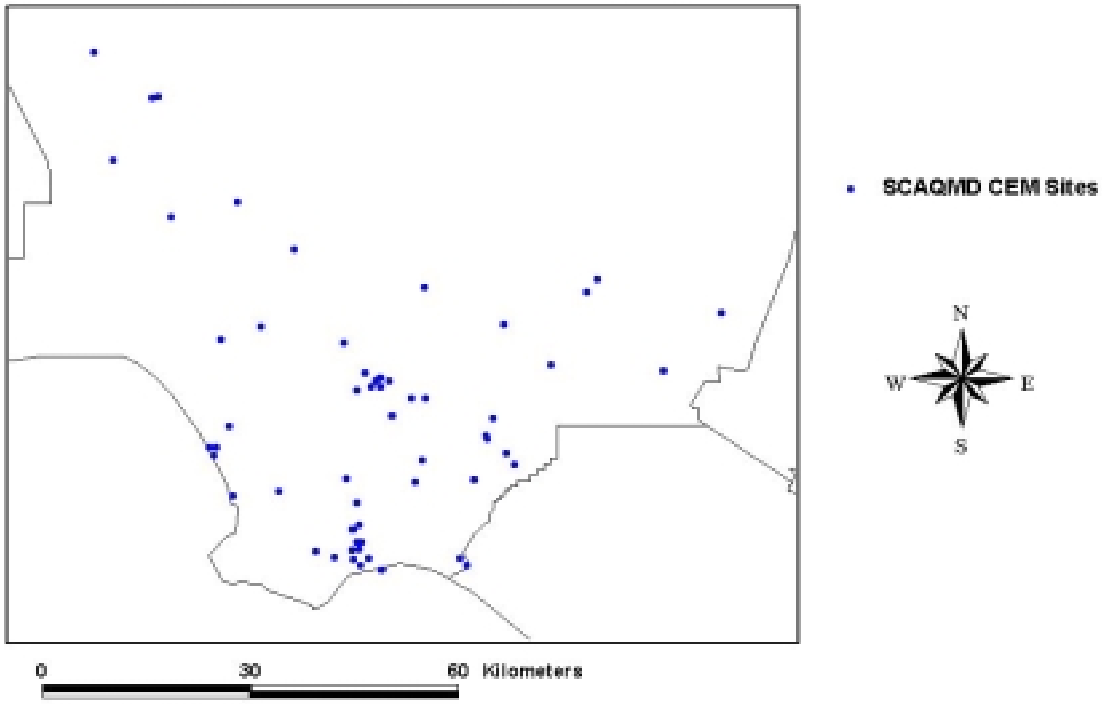


Figure 2-5. Locations of major point sources with CEMs in the SoCAB.

We obtained day-of-week and time-of-day variations in emissions activity data for selected area sources via written and telephone surveys of businesses and residences within about 4 km of selected air monitoring sites. The survey program was implemented by Freeman, Sullivan & Co. Potential residential respondents were selected by telephone interviews. Respondents were asked whether they would be willing to complete a set of 10 "Daily Activity" postcards that would identify household activities that might be related to air quality. Participants were asked to complete one card for each day of the 10-day period from September 29 to October 8, 2000. The postcards requested information about 10 activities that could potentially create ozone-affecting atmospheric emissions. For activities that took place, respondents were asked to check the time of day (i.e., morning, afternoon, and evening) that the activity occurred. The activities of interest were the use of

- barbecue grills
- consumer products (including hair spray, dyes, nail polish, polish remover)
- engine oils (including motor oils, gear oils or fluids, or brake fluids)
- fireplaces
- gasoline-powered equipment (including blowers, lawnmowers, weed whackers)
- paint (including varnishes, stains, thinners, solvents, or degreasers)
- paving or roofing (asphalt, tar)
- pesticides or fertilizers
- pouring of gasoline or diesel from or into a can
- vehicles (number of times a passenger vehicle departed from the household)

Businesses surrounding each monitoring site were randomly selected and were surveyed via telephone interviews conducted by trained callers. The survey program was implemented by Freeman, Sullivan & Co. If respondents agreed to participate, they were guided through a series of questions concerning the organization's operating hours and whether the organization engaged in activities that could potentially create ozone-forming emissions. Respondents were asked whether the organization used or operated

- engine oils (including motor oils, gear oils, or fluids)
- internal combustion (IC) engines, such as motors and compressors
- gas ovens
- pesticides and fertilizers
- solvents and paints

Business respondents were also asked to identify the number of employees working by day of week and by 4-hour time blocks starting at midnight each day.

2.2.4 Lawn and Garden Equipment

Day-of-week and time-of-day variations in emissions activity data were obtained for use of lawn and garden equipment sources via telephone surveys of landscape businesses and public institutions (e.g., schools, parks, golf courses, etc.) randomly selected throughout the SoCAB. Note that this survey is in addition to the written survey of residential use of gasoline-powered equipment (blowers, lawnmowers, weed whackers). Business and public institution respondents were asked about their use of

- edgers/trimmers/cutters
- mowers
- tractors
- chainsaws
- commercial turf equipment
- leaf blowers

2.3 RESULTS

2.3.1 On-road Mobile Sources: Surface Streets

Surface street traffic volumes were measured by Wiltech. Average relative traffic volumes by day of week and hour of day are shown in **Figures 2-6 through 2-10**. These figures represent average observations for four weekend days and six weekdays. Traffic volumes ranged from 7,000 to 25,000 vehicles per day on arterials and from 2,500 to 4,500 vehicles per day on collectors. At every location where vehicle classes were monitored, about 85-95% of the total traffic volume comprised passenger-type vehicles (including cars, pickup trucks, SUVs, vans, and motorcycles). In addition, passenger vehicles seemed to dominate the traffic at all the other sites (as judged by human observers).

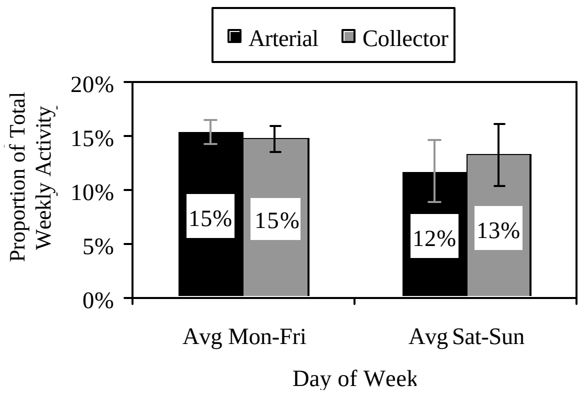


Figure 2-6. Average day-of-week traffic patterns observed for surface streets. Error bars bound 1 standard deviation.

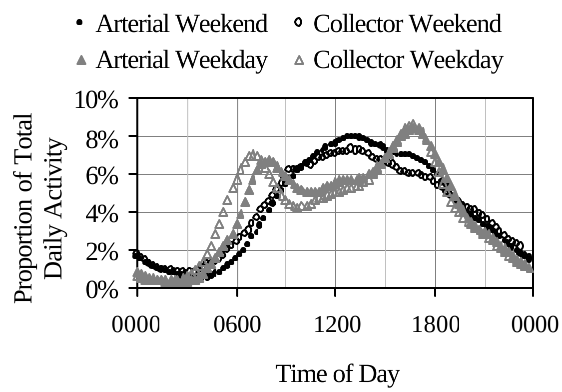


Figure 2-7. Average diurnal traffic patterns observed for surface streets.

Figure 2-6 shows the day-of-week patterns in total traffic volumes. The average weekday represents about 15% of total weekly traffic counts and the average weekend day represents about 12-13% of total weekly traffic counts. This represents a drop of 13-20% in total daily travel activity on weekend days relative to weekdays. In addition, diurnal patterns of travel activity differed between weekends and weekdays (see Figure 2-7). On weekdays, bimodal distributions were observed with peaks in activity corresponding to the morning and afternoon rush hours around 0730 and 1700 PDT. On weekends, single-mode distributions were observed with broad peaks in activity centered around 1330 PDT. Further analyses show that distinct traffic patterns also exist between Saturday and Sunday, as shown later in this section.

Figures 2-8a and 2-8b show that total daily travel activity for buses and trucks dropped 44-67% on weekends. The diurnal patterns for buses (not pictured) were fairly consistent between weekdays and weekends and followed a single-mode distribution with a broad peak between 1130 and 1430 PDT. Figure 2-9 illustrates the diurnal traffic patterns observed for trucks. Heavy-duty truck traffic is the only on-road category that showed a different pattern of activity on freeways relative to surface streets. As shown in Figure 2-9, heavy-duty traffic has a single peak in activity on freeways and a dual-mode peak in traffic activity on surface streets; all other on-road categories have surface street activity similar to freeway traffic. This distribution could be a result of vehicle misclassification errors, where multiple passenger cars traveling close together were mistaken for HD trucks. However, it should be noted that the San Gabriel River Parkway site, which is heavily influenced by a freeway off-ramp, did not show a noticeable bimodal distribution in HD truck activity and was fairly consistent with interior basin freeway patterns. Surface street locations that were less closely associated with freeways displayed strong bimodal HD vehicle traffic patterns on weekdays. In addition, the fact that the WD/WE reduction in total daily HD vehicle activity was 67%, which is much larger than the 13% reduction seen for passenger vehicles and is more consistent with reductions noted in the freeway analysis, suggests that the loop sensors identified HD trucks relatively accurately.

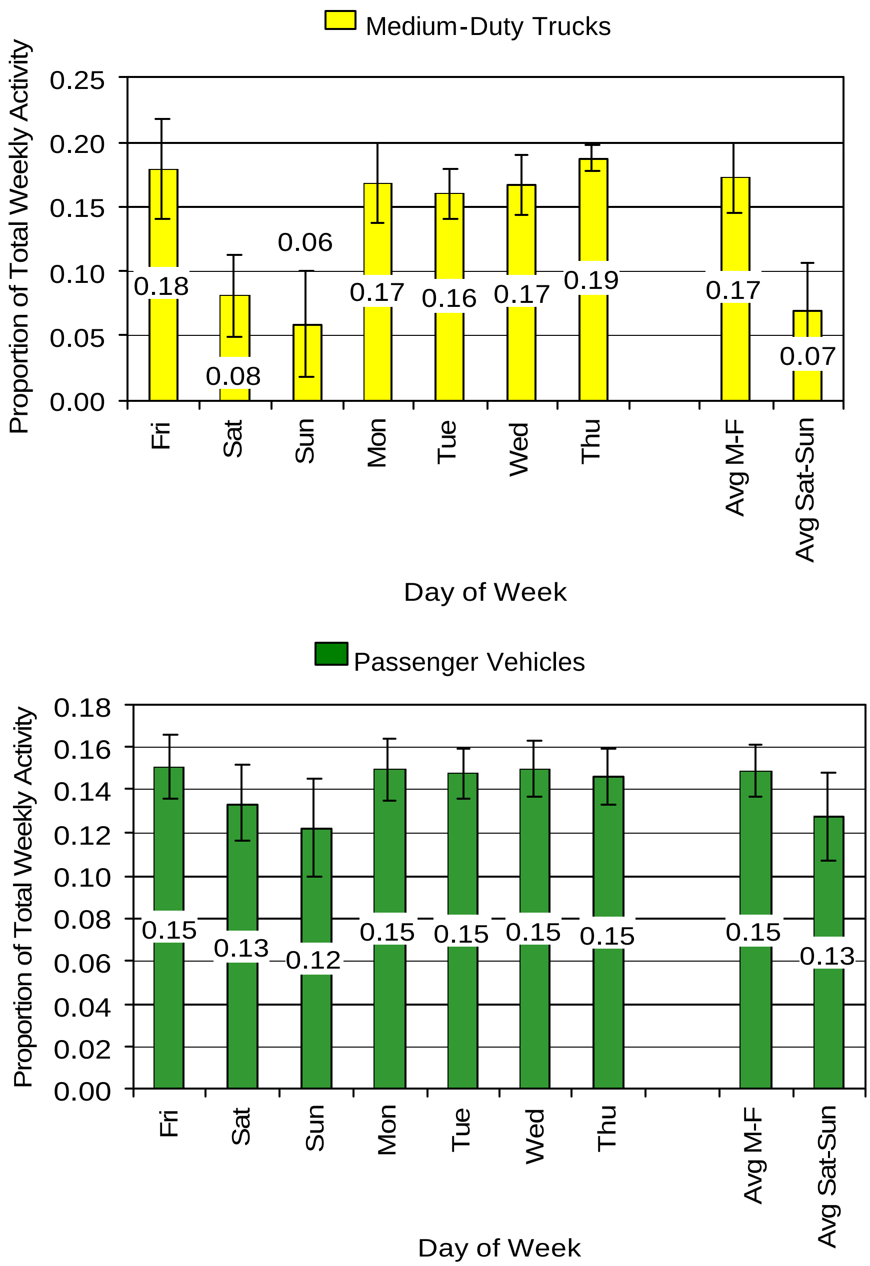
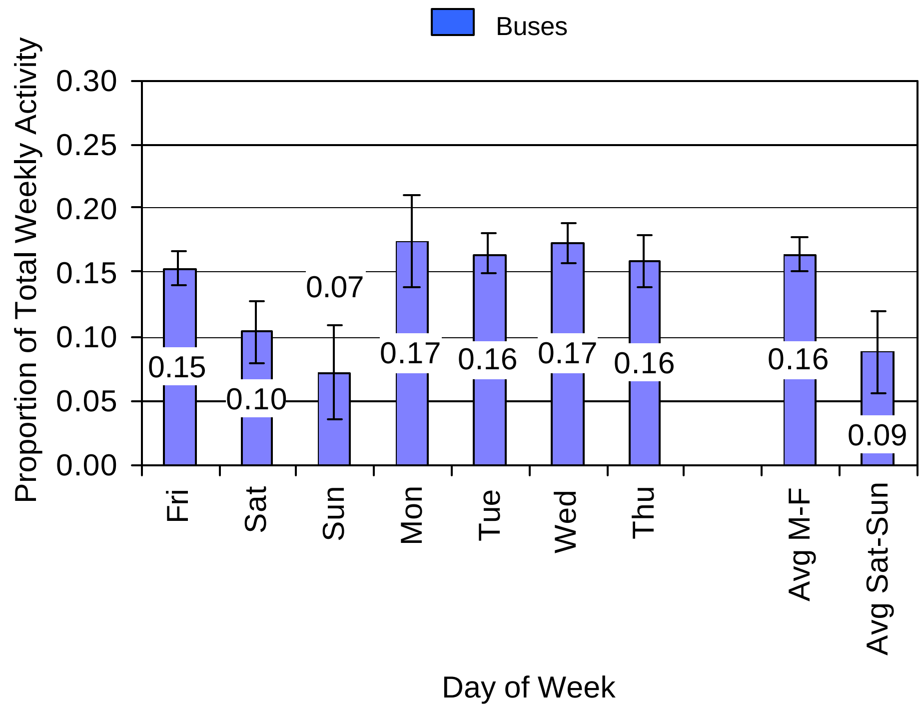


Figure 2-8a. Average day-of-week traffic patterns observed for passenger vehicles and medium-duty trucks on surface streets. Error bars bound 1 standard deviation.



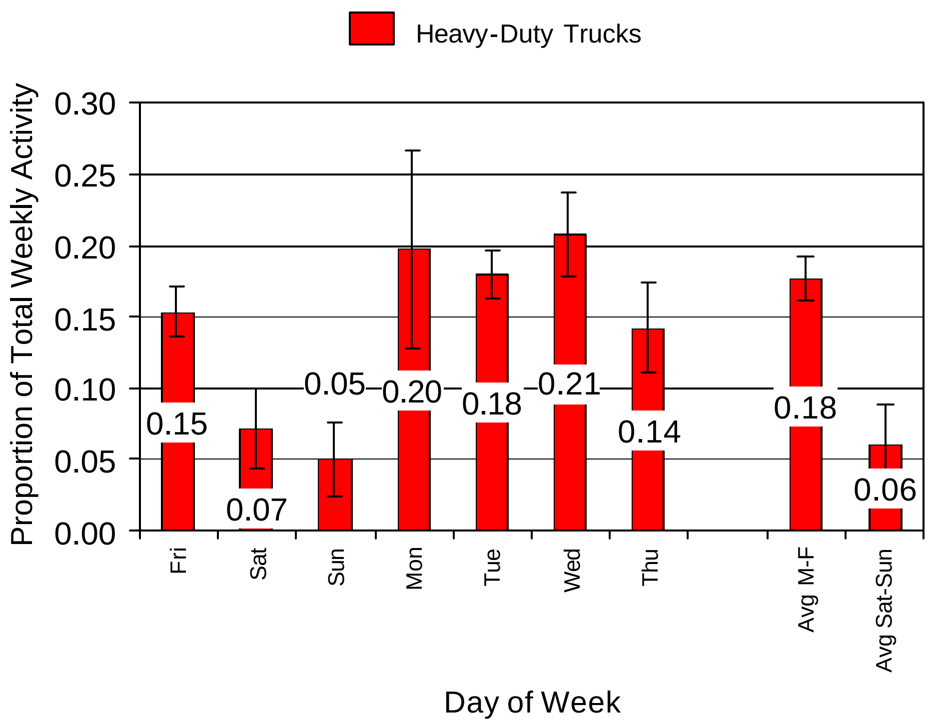


Figure 2-8b. Average day-of-week traffic patterns observed for heavy-duty trucks and buses on surface streets. Error bars bound 1 standard deviation.

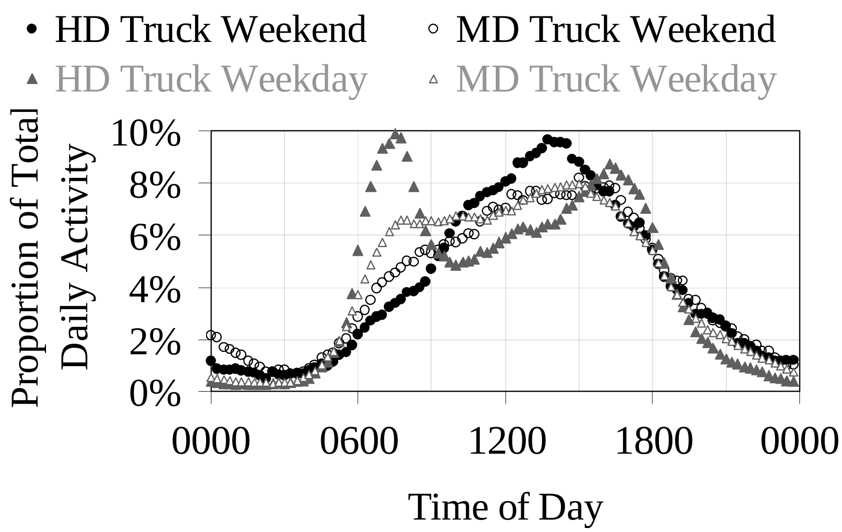


Figure 2-9. Average diurnal truck traffic patterns observed for surface streets. (MD = medium-duty, HD = heavy-duty)

Figure 2-10 shows the proportion of total urban traffic that was observed by hour of day for Monday through Thursday, Friday, Saturday, and Sunday. The peak traffic volume is from 1700 to 1800 PDT, regardless of the day of week, although the afternoon peak on weekends (and the only peak on Sunday) is about one hour earlier than the weekday afternoon peak. Monday through Thursday and Friday traffic patterns are quite similar, showing a local peak in traffic volume at 0900 PDT. On Saturday, this local peak is shifted to 1100 to 1200 PDT (two hours long). On Sunday, there is no additional peak in local traffic activity, as on Saturday.

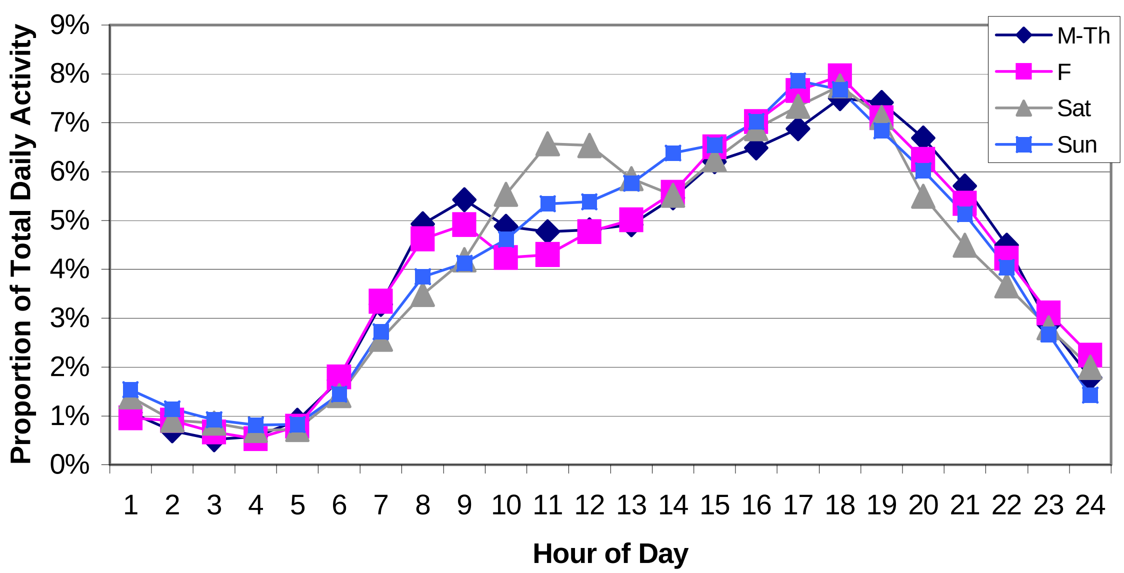


Figure 2-10. Average WD/WE diurnal traffic patterns observed on surface streets at four locations by hour of day for Monday through Thursday (M-Th), Friday (F), Saturday (Sat), and Sunday (Sun).

2.3.2 On-road Mobile Sources: Freeways

Traffic volumes on freeways were analyzed by day of week, hour of day, and vehicle type. The variations in WD/WE travel patterns did not show significant differences between annual and seasonal time periods and for the two-week study period that coincided with data collection on surface streets (September 29 to October 11, 2000). Thus, differences in driving behavior on freeways by day-of-week appear to be fairly consistent over the course of a year in the SoCAB.

Figure 2-11 shows the average fleet mixes and traffic volumes for the inflow/outflow sites (Indio and Castaic), the interior basin sites, and the Long Beach site. HD vehicles comprise relatively greater fractions of the total traffic volumes at the inflow/outflow and Long Beach sites than at the interior basin sites. HD vehicle volumes decrease on weekends by factors of 2 to 4 throughout the basin, while light-duty (LD) vehicle volumes decrease slightly on weekends in the interior basin but increase slightly at the inflow/outflow sites. **Table 2-3** shows the relative change from average weekday (Monday through Thursday) compared to Friday, Saturday and Sunday for each of the WIM sites.

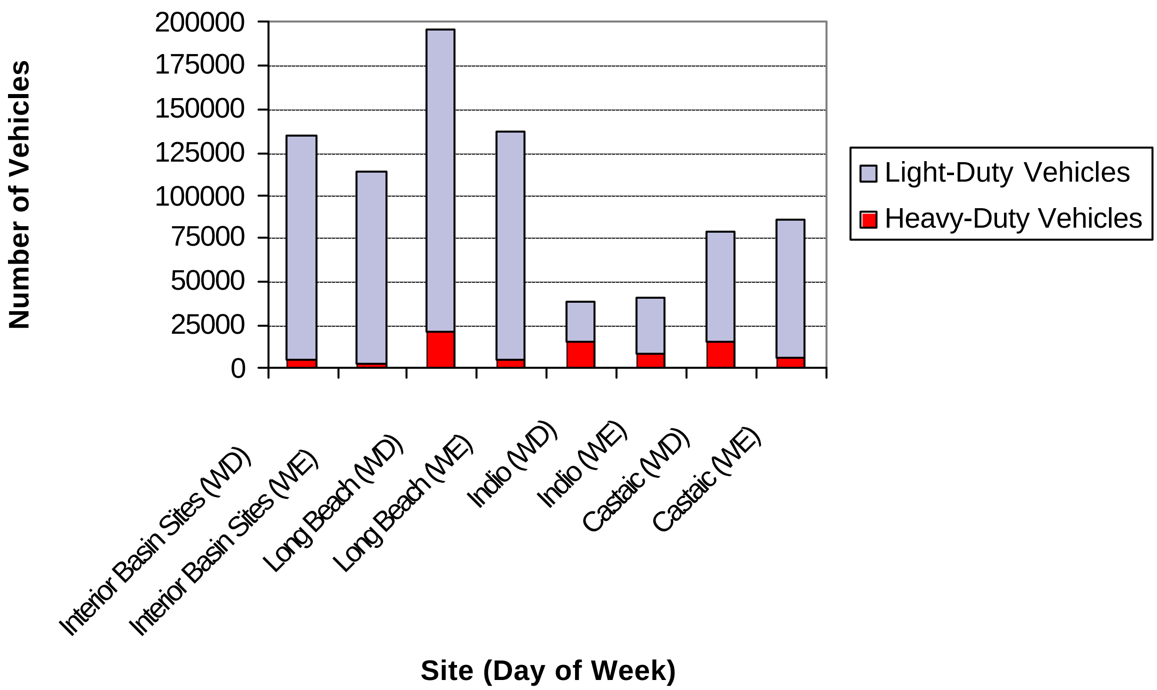


Figure 2-11. Average fleet mixes and travel volumes observed at freeway WIM sites on weekdays and weekends. (Note: Indio is located in the eastern region of the SoCAB, Castaic is in the northwestern region, and Long Beach is on the access route to the Port of Long Beach).

Table 2-3 Traffic change by day of week.

	Relative change by day of week compared to weekday average		
Site	Friday	Saturday	Sunday
Indio (LDV)	67%	26%	67%
Indio (HDV)	-5%	-42%	-41%
Castaic (LDV)	36%	28%	36%
Castaic (HDV)	-5%	-53%	-62%
Fontana (LDV)	19%	5%	8%
Fontana (HDV)	4%	-51%	-60%
Long Beach (LDV)	6%	-13%	-33%
Long Beach (HDV)	-2%	-74%	-83%
Artesia (LDV)	3%	-23%	-33%
Artesia (HDV)	-12%	-79%	-71%
Glendora (LDV)	9%	-6%	-19%
Glendora (HDV)	-4%	-57%	-72%
VanNuys (LDV)	7%	-2%	-20%
VanNuys (HDV)	-3%	-44%	-66%
Irvine (LDV)	5%	-15%	-30%
Irvine (HDV)	-1%	-59%	-76%

Figure 2-12 shows typical LD vehicle volumes by day of week and hour of day. LD vehicle patterns for Long Beach are similar to those for interior basin sites. At these locations, weekday LD vehicle volumes follow bimodal distributions with peaks during the morning and afternoon rush hours, and weekend LD vehicle volumes peak around midday. At the inflow/outflow sites, weekend LD volumes follow an attenuated bimodal distribution. They are also relatively high on Friday and Sunday afternoons. The increased volumes on Friday and Sunday afternoons are plausibly a result of vehicles departing for and returning from weekend recreation outside the SoCAB.

HD vehicle volumes by day of week and hour of day are shown in **Figure 2-13**. HD vehicle volumes are very high at the Long Beach site. Diurnal HD vehicle volumes are similar for the interior basin and Long Beach sites in that the volumes tend to peak at midday. At the inflow/outflow sites, HD vehicle volumes peak in the evenings at Indio (which is in the eastern region of the SoCAB on Interstate 10) and in the morning and midday at Castaic (which is in the northwestern region of the SoCAB on Interstate 5).

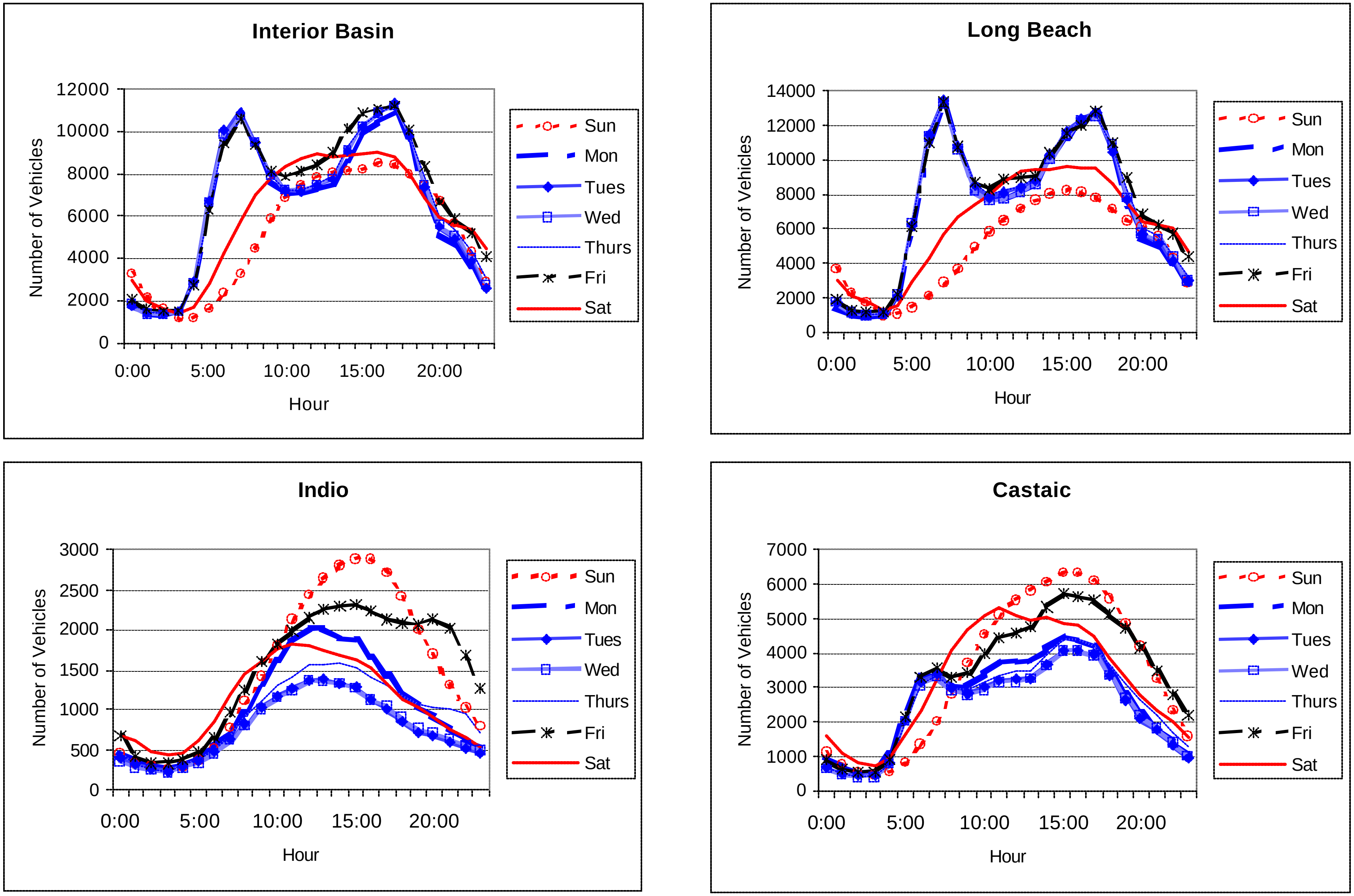


Figure 2-12. Average light-duty traffic volumes by hour of day and day of week observed at freeway WIM sites. Note that different scales are used to improve readability.

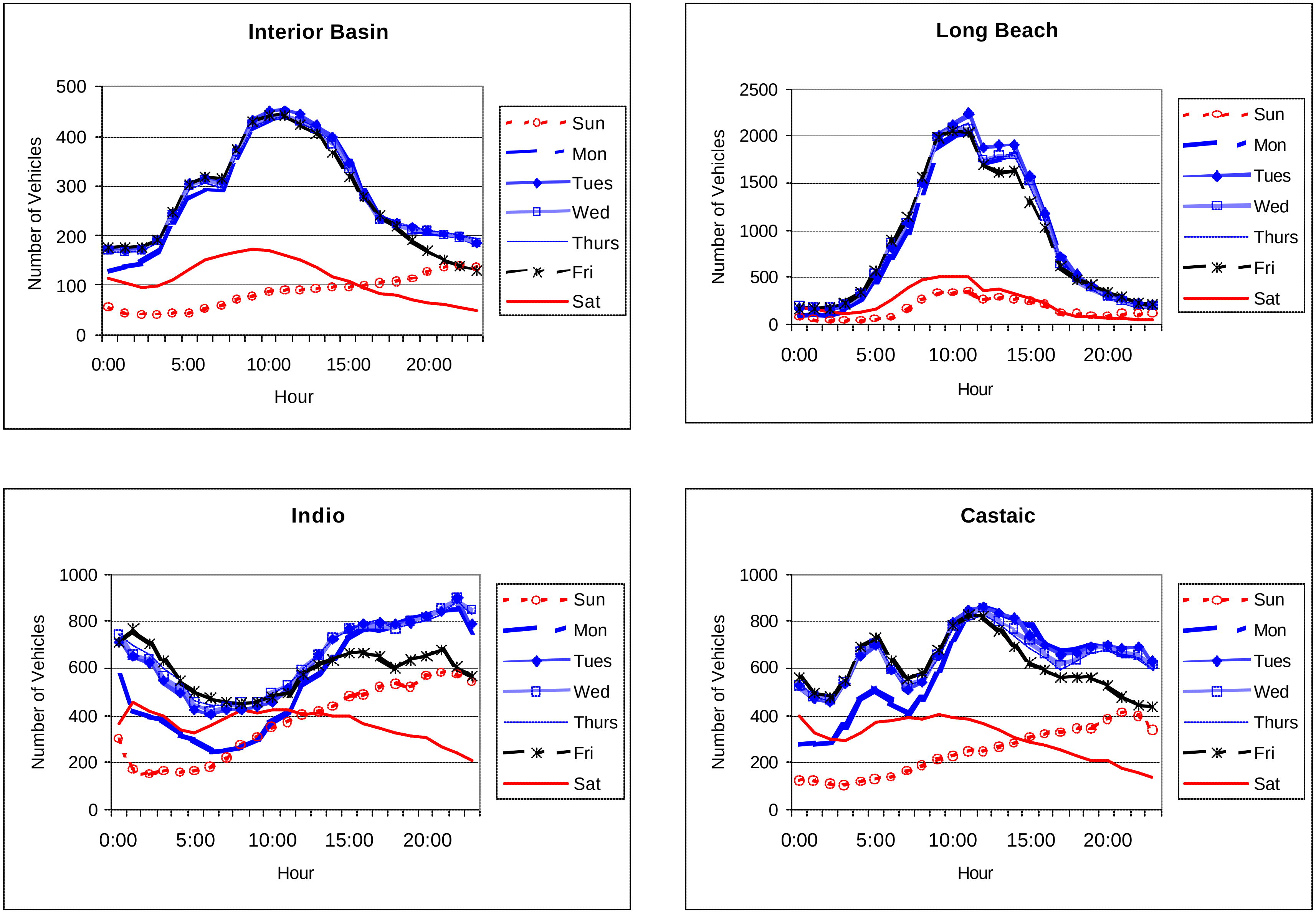


Figure 2-13. Average heavy-duty traffic volumes by hour of day and day of week observed at freeway WIM sites. Note that different scales are used to improve readability.

2.3.3 Summary of On-road Results

Significant WD/WE variations in traffic volumes were observed at a number of freeways and surface streets throughout the SoCAB. The variations follow predictable patterns that depend upon geography, road class, and vehicle type. Preliminary conclusions include the following:

- On weekends in urban zones, daily traffic volumes (which are dominated by light-duty vehicles) are about 15-30% lower relative to weekday volumes and tend to peak around midday rather than during the morning and afternoon rush hours. Traffic counts also show a distinct difference between Saturdays and Sundays. Sunday traffic is further reduced compared to Saturday and weekday traffic and has a slightly delayed peak compared to that of Saturdays.
- On weekends, truck and bus activities decrease to a far greater extent—by factors of 2 to 4—than do passenger vehicle activities.
- In areas just beyond the urban zones, daily traffic volumes increase somewhat on weekends and tend to peak on Friday and Sunday late afternoons.
- When segregated by vehicle class, traffic patterns for freeways and surface streets in the central urban zone are similar in many respects. Heavy-duty truck patterns are a possible exception. On weekdays, a bimodal distribution in heavy-duty truck activity was observed, with modes at roughly 8 a.m. and 5 p.m., on three surface streets, while single-mode patterns were observed on freeways and one freeway-influenced surface street.

2.3.4 Lawn and Garden Equipment

The CARB emission inventory shows that lawn and garden equipment emissions account for only 0.4% and 0.2% of the total ROG and NO_x inventories, respectively. However, because of the possibility of a highly skewed weekend use pattern, this category was investigated further. **Figure 2-14** shows the distribution of emissions from lawn and garden equipment as reported by the CARB.

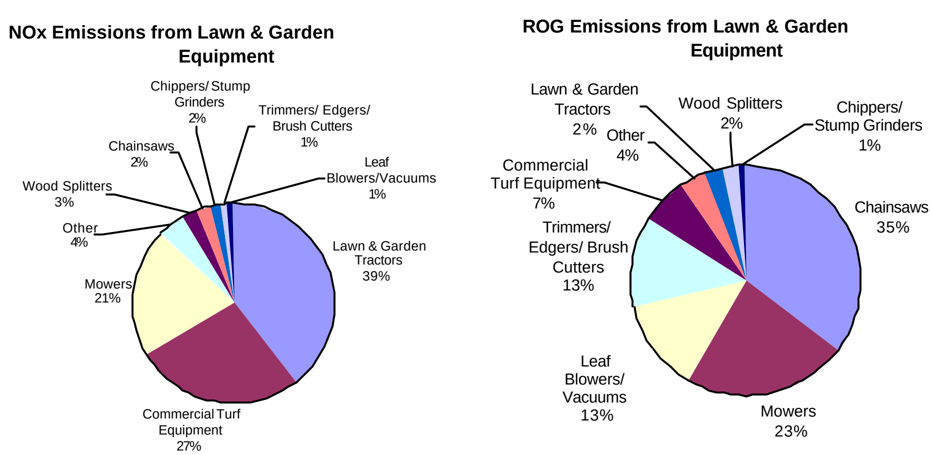


Figure 2-14. NO_x and ROG lawn and garden equipment emissions in the SoCAB.

Day-of-week variation in the use of lawn and garden equipment was investigated by surveying commercial, institutional, and residential users of the equipment (see Appendices B and D). Surveys were obtained from 150 telephone interviews of commercial businesses or institutions. **Figures 2-15 and 2-16** show the WD/WE pattern of lawn and garden equipment use by commercial and institutional users. (Residential use of lawn and garden equipment is presented in Section 2.3.6.) As shown in Figure 2-15, commercial and institutional use of lawn and garden equipment is reduced by at least 80–90% on weekends relative to weekdays. The survey results of commercial and institutional use of lawn and garden equipment also showed that there was little variation in the diurnal activity patterns by day-of-week. (This is also in contrast to the activity pattern of residential users, which showed a tendency toward increased use in the afternoon, particularly on Fridays, compared to all other days.)

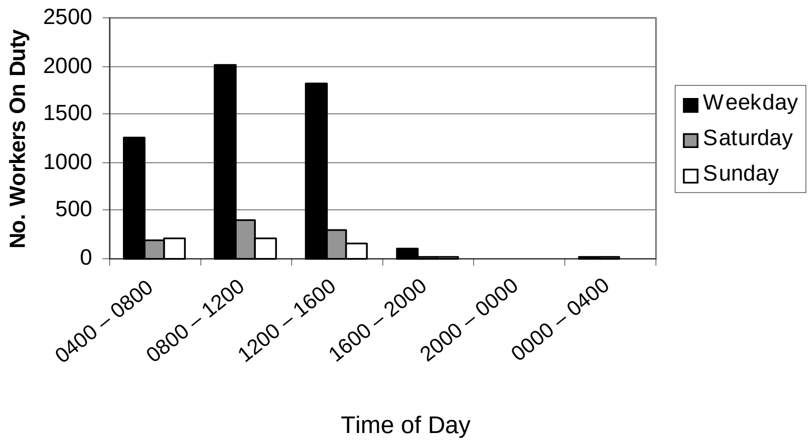


Figure 2-15. Commercial/institutional number of workers by day of week and time of day for lawn and garden equipment usage.

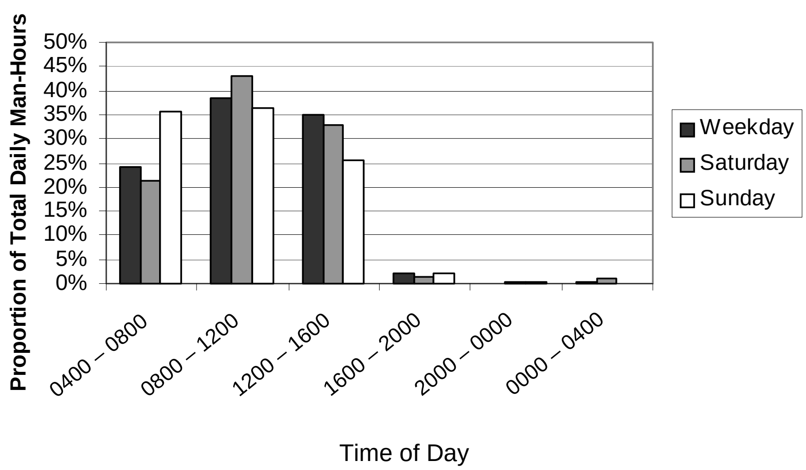


Figure 2-16. Commercial/institutional proportion of work hours by day of week and time of day for lawn and garden equipment usage.

2.3.5 Stationary Point and Area Sources

CEM NO_x data collected in the SoCAB, obtained from the SCAQMD for 1999 and 2000, were used to estimate major point source activity in the SoCAB. Total NO_x emissions (about 50 tons per day, on average) from the point sources reporting CEM data represent about 75% of total point source NO_x emissions in the SoCAB and comprise approximately 50% of the summertime total stationary and area source NO_x emissions (see Tables 2-1 and 2-2).

Figure 2-17 shows the average WD/WE NO_x emissions during the summers of 1999 and 2000. In 1999, on average, NO_x emissions decreased on Friday by 13%, on Saturday by 26%, and on Sunday by 22%, relative to Monday through Thursday. In 2000, NO_x emissions, on average, decreased on Fridays by 0%, on Saturdays by 7%, and on Sundays by 14%, relative to Monday through Thursday.

Figure 2-18 shows the daily total point source NO_x emissions for the sites analyzed on a day-to-day basis during summer 2000. The figure illustrates the variability in point source emissions and shows that there is a base level below which the total emissions do not fall. A detailed investigation as to the causes of the emission spikes was not possible since the identity of each source was not available due to confidentiality of the CEM data.

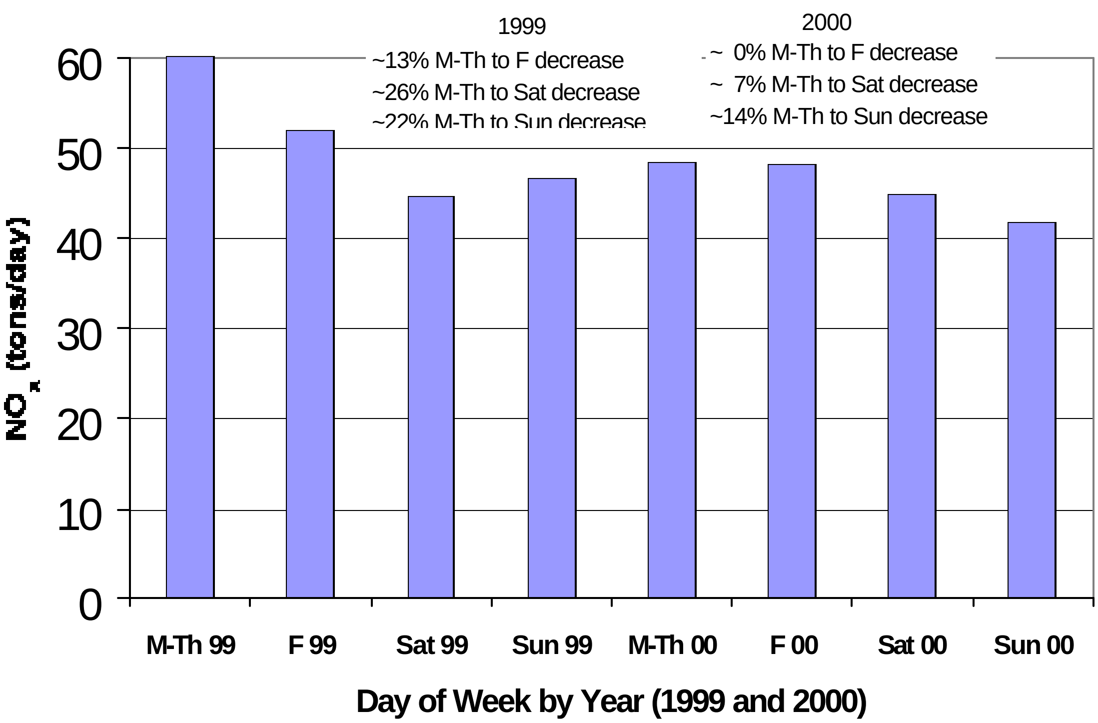


Figure 2-17. WD/WE NO_x emissions from CEM sources in the SoCAB. In 1999, Friday (F) through Sunday (Sun) emissions were 13-26% lower than Monday through Thursday (M-Th) emissions. In 2000, Friday through Sunday emissions averaged 0-14% less than Monday through Thursday emissions.

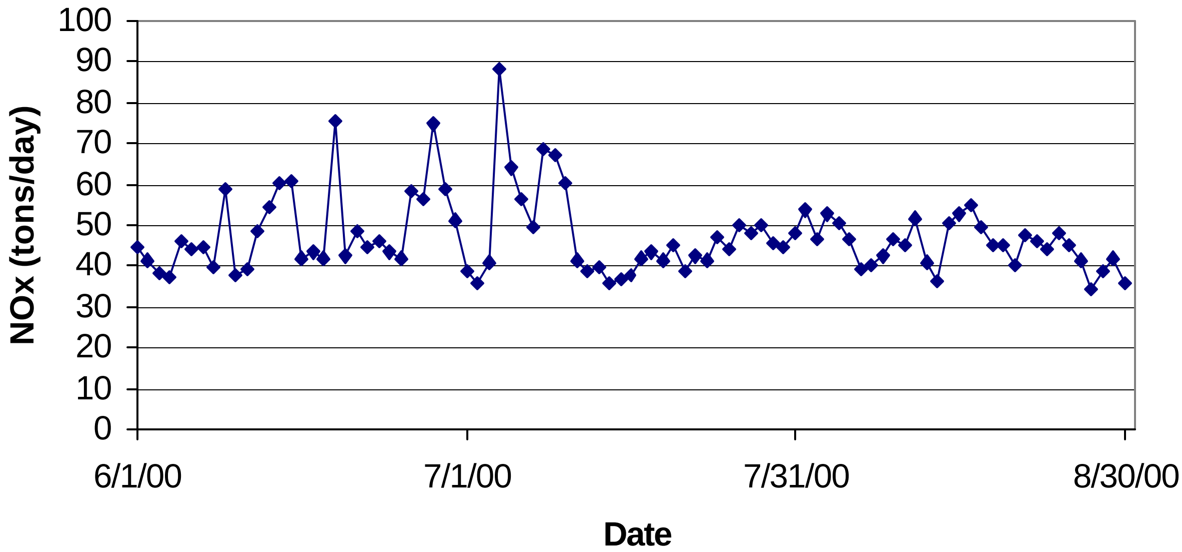


Figure 2-18. Daily NO_x emissions from CEM sources in the SoCAB from June to August 2000.

There are no CEM-type emissions reported for ROG. The types of processes that are associated with significant ROG emissions (e.g., surface coatings and fugitive or evaporative losses) do not necessarily correlate with combustion-related NO_x emissions. Thus, while we can show that point source NO_x emissions decreased on weekends, we cannot quantify the day-of-week effect on ROG emissions from point sources, but it is believed that they are also reduced due to reduced business activity on weekends.

2.3.6 Area Sources: Residential Survey Results

Four hundred fifty residences were surveyed in this study. Average residential activity for selected area source categories by day of week is shown in **Figure 2-19**. Three distinct WD/WE activity patterns are observed, depending on activity type: (1) higher activity on the weekend relative to a weekday, (2) higher activity on Friday and Saturday relative to Monday through Thursday and Sunday, and (3) no variation by day-of-week. There were no cases where weekday activity was significantly higher than weekend activity.

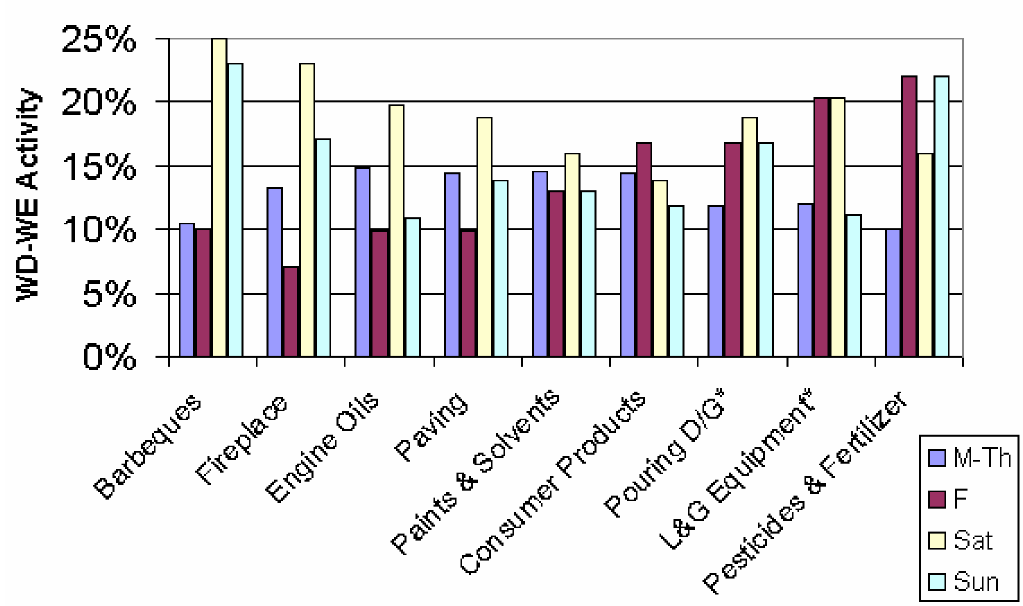


Figure 2-19. WD/WE activity for residential area source emission categories. (D/G = diesel/gasoline and L&G = lawn and garden equipment)

As can be seen in Figure 2-19, a number of area source categories are enhanced on weekends, including use of lawn and garden equipment, barbecues, fireplaces, pesticides, and fertilizers, and pouring diesel or gasoline. Use of lawn and garden equipment as well as barbecues increases by about a factor of two on weekends relative to weekdays. Fertilizer and pesticide applications increase by 50% on the WE relative to a weekday. In contrast, use of paint and solvents and consumer products is relatively independent of the day of the week.

In addition to day-of-week activities, the survey asked respondents to track activities by time of day. Diurnal patterns of residential area source emissions activity are depicted in **Figures 2-20a, 2-20b, and 2-20c**. Diurnal patterns varied considerably from a strong day-of-week influence to no variation by day of week. For example, consumer products and engine oil usage showed diurnal profiles that are relatively independent of day of week, while barbecue usage occurs more often in the afternoon on the WE than on a WD. Paints and solvent usage occurs slightly more often in the afternoon on the WE than on a WD.

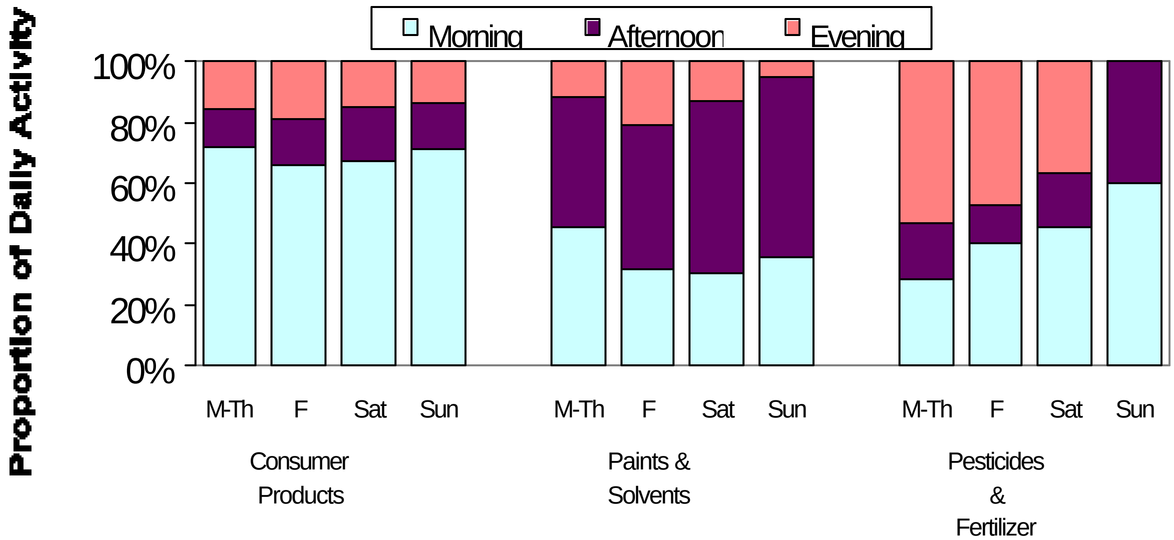


Figure 2-20a. Average day-of-week diurnal activity patterns for use of consumer products, paints and solvents, and pesticides and fertilizers.

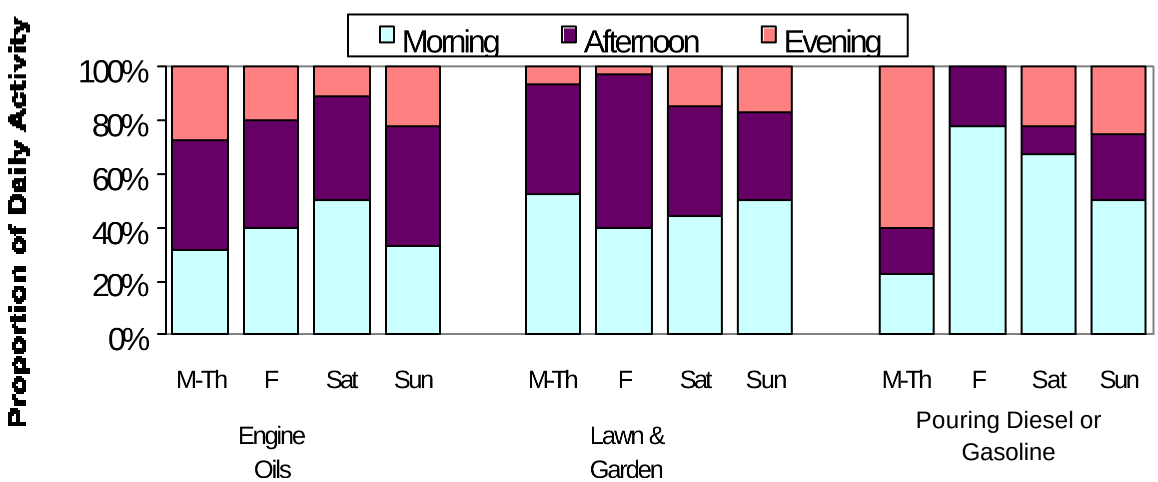


Figure 2-20b. Average day-of-week diurnal activity patterns for use of engine oils, lawn and garden equipment, and pouring diesel or gasoline.

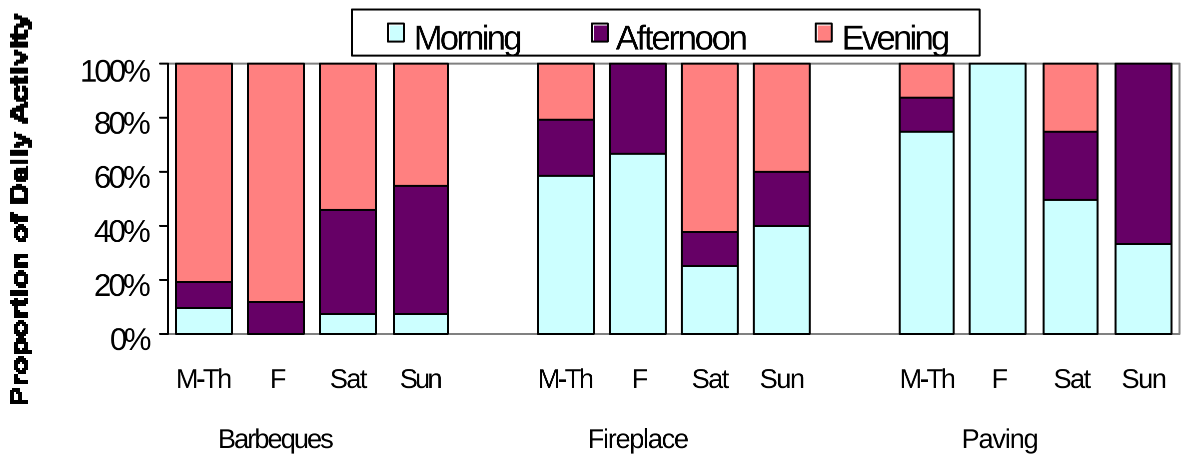


Figure 2-20c. Average day-of-week diurnal activity patterns for use of barbeques and fireplaces and for paving.

While the results of this survey are enlightening, it is important to remember that the number of respondents was relatively small (about half of the sample of 450 on any given day) and the residences surveyed were limited to the neighborhoods surrounding the selected air quality monitoring sites. Thus, the results may not be representative of the entire SoCAB or other areas of the State. Because of limited sample size, responses for some area source categories may not be statistically significant or meaningful.

2.3.7 Area Sources: Business Survey Results

A total of 131 businesses was surveyed in this study. Average business activity for selected area source categories by day of week is shown in **Figure 2-21**. Only one pattern of variation in business activity by day of week is observed. There is a substantial reduction in all activities on the weekend compared to weekdays, activity on Saturdays being less than that on weekdays and activity on Sundays being even further reduced. Specifically, activity declines on Saturday by factors of 2 to 5 relative to weekdays and on Sunday by factors of nearly 5 to 20 relative to weekdays, as shown in Figure 2-21.

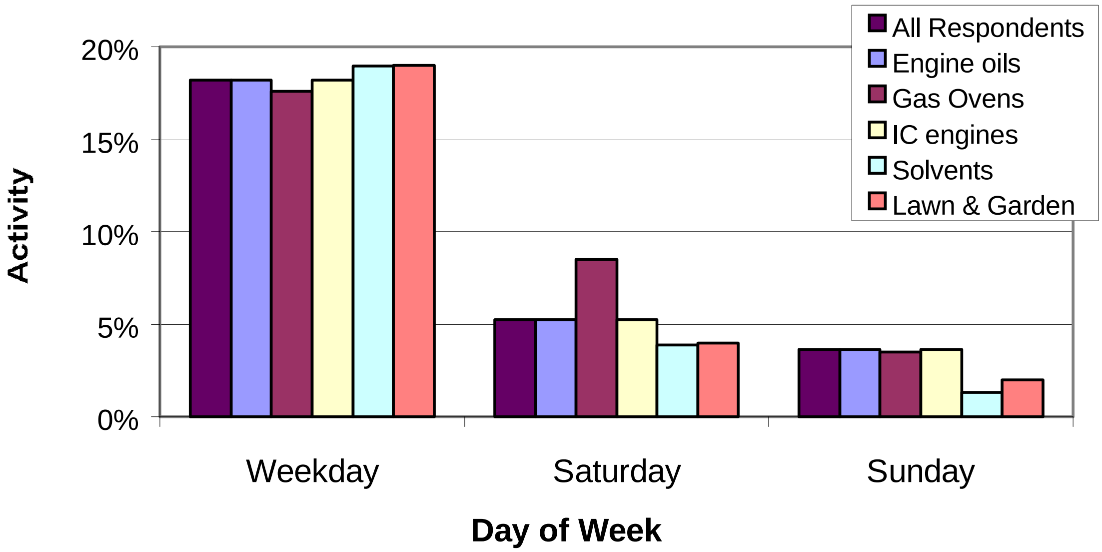


Figure 2-21. Business WD/WE activity for source emission categories.

The weekday, Saturday, and Sunday diurnal activity patterns for the selected business area source categories are depicted in **Figures 2-22a, 2-22b, and 2-22c**. In contrast to a similar day-of-week pattern for all source types, there are a number of interesting features to the diurnal variations in business activity by source type. For example, on weekdays, single-mode distributions were observed for all business activities of interest, with peak activity corresponding to the middle of the day from 0800 to 1600 PDT. The percentage of respondents who used engine oils and IC engines was essentially identical; therefore, we show only one of these categories in each figure for clarity. Engine oils, IC engines, and lawn and garden equipment categories exhibit a rapid rise of activity from 0400 to 0800 PDT. Businesses employing gas ovens exhibit prolonged use into the evening, from 1600 PDT to midnight. On Saturday (Figure 2-22b), single-mode distributions were also observed, although gas oven usage was more pronounced in the middle of the day, from 0800 to 1600 PDT, than on weekdays. On Sunday (Figure 2-22c), both single-mode and flat distributions were observed. Lawn and garden equipment activity shows a single-mode distribution similar to that on weekdays, yet with higher activity from 0400 to 0800 PDT than at any other time. For businesses using engine oils, IC engines, and gas ovens, the diurnal activity distribution was generally flat with almost no tendency towards more activity in any particular 4-hour time block. Appendix F provides further details on the business survey responses.

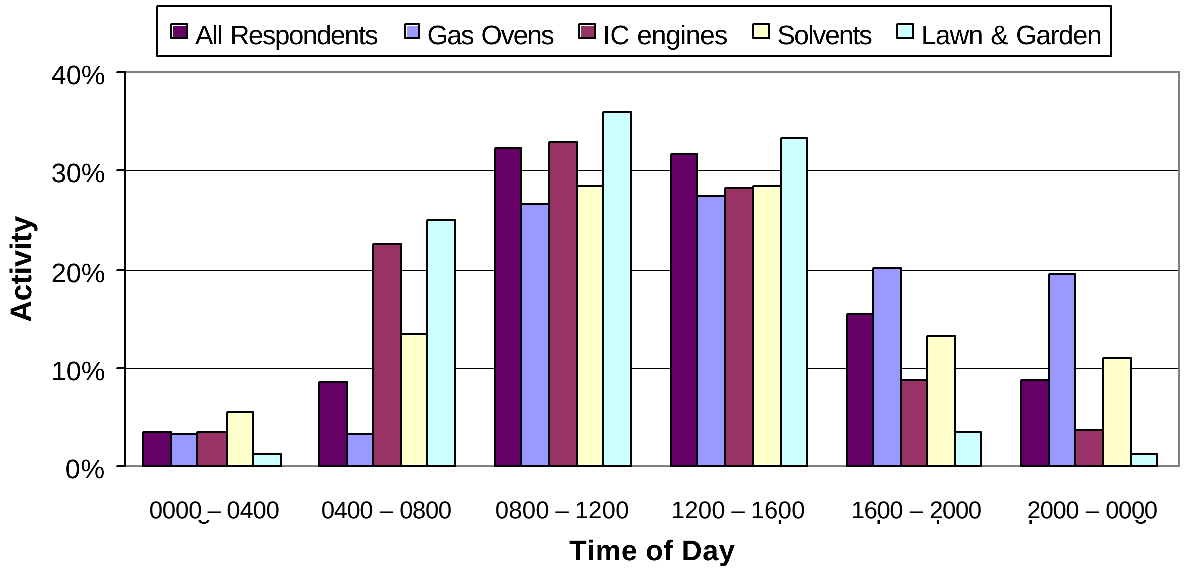


Figure 2-22a. Business activity by 4-hour time block on weekdays (Monday through Friday).

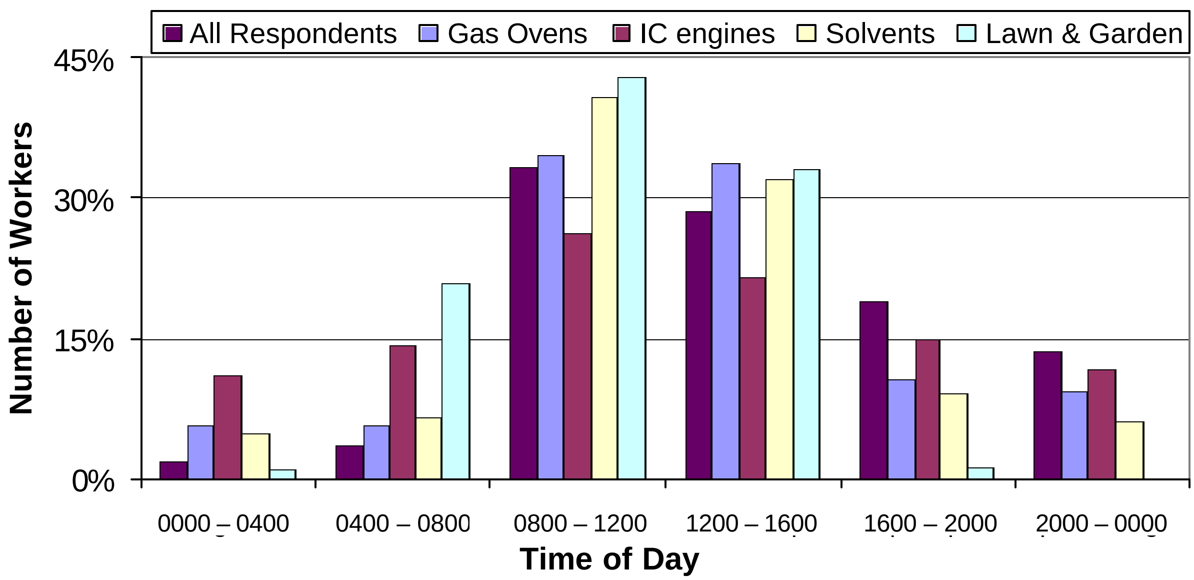


Figure 2-22b. Business activity by 4-hour time block on Saturdays.

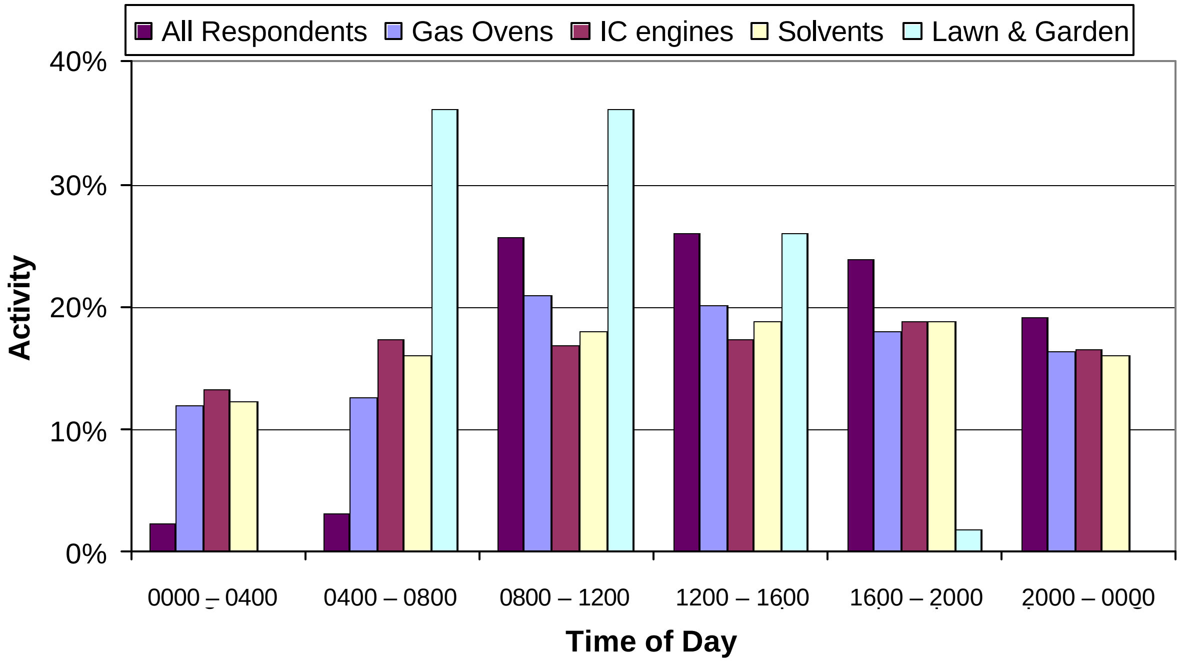
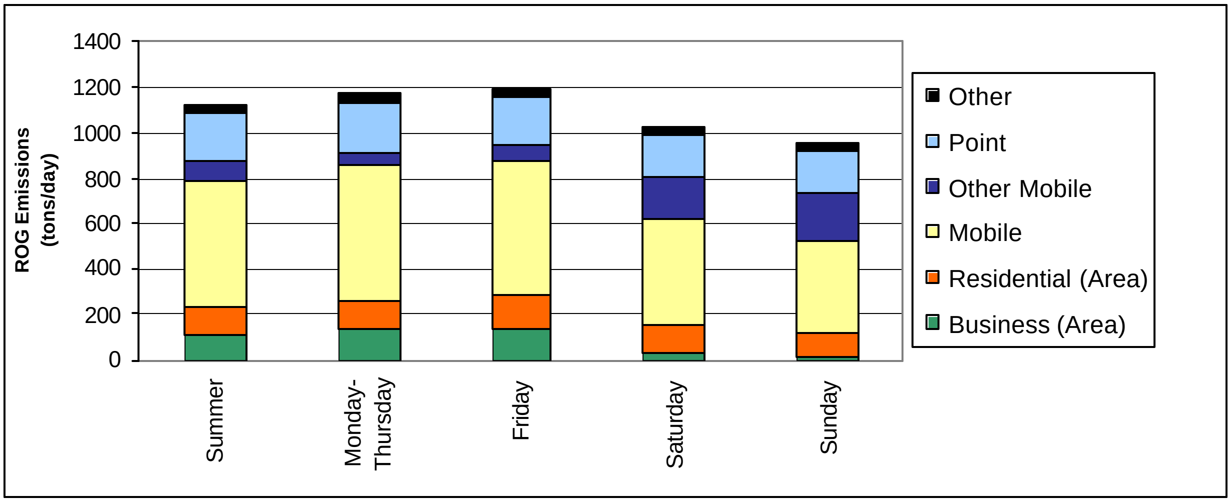


Figure 2-22c. Business activity by 4-hr time block on Sundays.

2.4 DISCUSSION OF FINDINGS

The results of the survey of residential and business area source activities, examination of CEM data, and the surface street and freeway traffic volumes provide clear evidence of significant day-of-week variations in activity within each category type. To better understand the net effect of all of the variations combined, a set of category-specific scaling factors by day of week were developed from the results described above. Additionally, a day-of-week recreational boat activity profile was generated using data from a special ARB study. These day-of-week scaling factors were then applied to the summertime daily average emissions reported by the CARB as summarized in **Table 2-1**. The resulting day-of-week emission estimates by category were used to develop SoCAB-wide total emissions by day of week. Note that emissions were held constant for those categories without day-specific activity factors. **Figure 2-23** depicts the results for 2000. Appendix H provides further details on the development of temporal activity profiles. Appendix I provides detailed tables showing year 2010 estimated emissions by day of week.



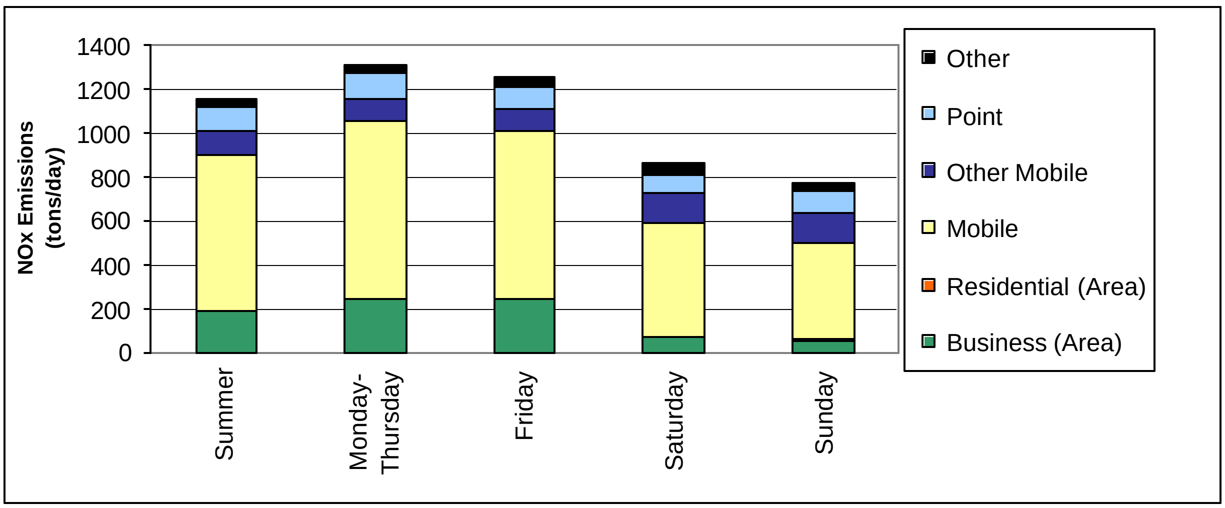


Figure 2-23. Estimated 2000 day-of-week emissions in the SoCAB.

As shown in Figure 2-23, total ROG and NO_x emissions decrease from weekdays to Saturday and decrease further on Sunday. The net emission changes result from the combination of variations in emissions among individual source categories as described above. As noted above, the largest emissions variations are associated with source categories that are large in magnitude and vary significantly in activity by day of week. As shown in Figure 2-23 and discussed previously, the single largest category of emissions is mobile sources and emissions in this category vary significantly by day of week. As a result, the drop in mobile source emissions activity is the single largest contributor to emission changes on the weekend. Second most in importance are emissions associated with small businesses, which decrease dramatically on weekends. Reductions in point source emissions on weekends are offset by increases in other mobile source emissions on weekends.

Basin-wide ROG emissions decrease by 12% from weekday to Saturday; 18% from weekday to Sunday, and NO_x emissions decrease 35% from weekday to Saturday and 41% from weekday to Sunday. Heavy-duty trucks account for 7% of ROG and 25% of NO_x emissions from Monday through Thursday, 3% of ROG and 15% of NO_x on Saturday, and 2% of ROG and 12% of NO_x on Sunday. Thus, heavy-duty truck emissions as a percentage of total emissions decline by about 50% on the weekend relative to a weekday. Recreation boats emit 3%, 17% and 20% of total ROG emitted on Monday through Thursday, Saturday, and Sunday. Thus, recreational boats account for six times as much emissions on the weekend relative to a weekday and become a significant contributor to total ROG emissions on the weekend. Lawn and garden equipment emissions for Monday through Saturday account for 2% of ROG and 0.2% of NO_x, and on Sunday 1% of ROG and 0.1% of NO_x. Thus, lawn and garden equipment emissions represent a small fraction of total emissions and do not increase (but actually decrease) on the weekend relative to a weekday.

During the morning hours (6 a.m. to 9 a.m.), NO_x emissions decrease 49% from weekdays to Saturday and by 52% from weekdays to Sunday (see **Figure 2-24**). ROG emissions decrease by 20% from weekdays to Saturday and by 23% from weekdays to Sunday (see **Figure 25**). Thus, there is larger decrease in NOx emissions relative to ROG emissions on weekends.

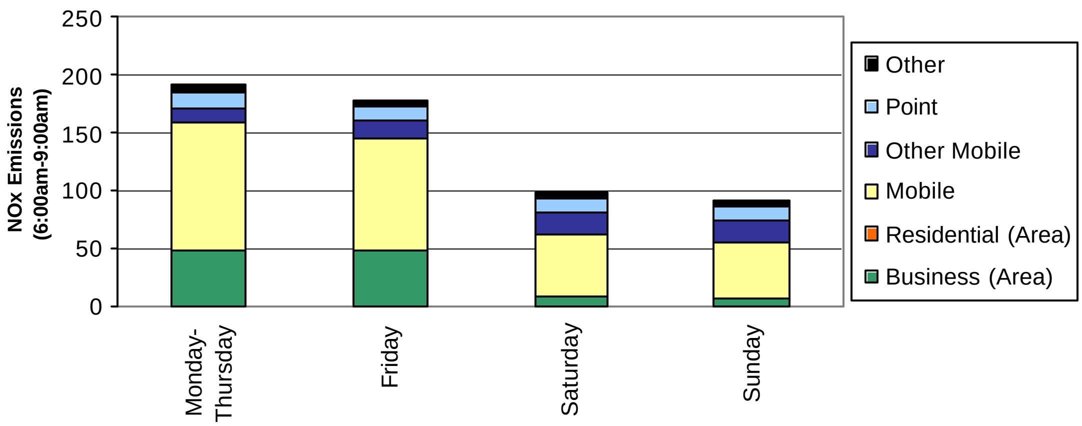


Figure 2-24. NO_x decreases 49% from weekdays to Saturday; 52% from weekdays to Sunday (6 a.m. to 9 a.m.).

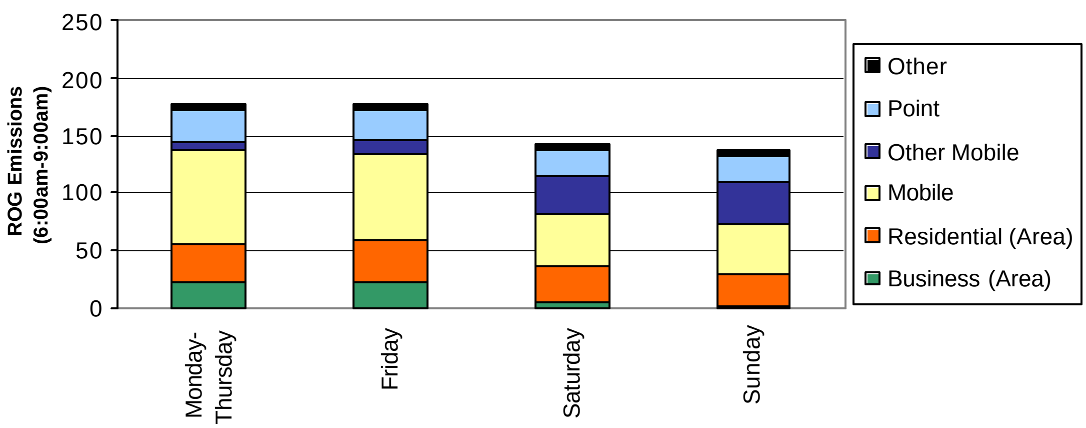


Figure 2-25. ROG decreases 20% from weekdays to Saturday; 23% from weekdays to Sunday (6 a.m. to 9 a.m.).

One measure of the potential ozone impact of the net emission changes on weekends is to compare the basin-wide molar ratio of ROG to NO_x emissions. Higher ratios are generally more favorable for ozone production. **Figure 2-26** shows that the ROG-to-NO_x ratio is higher on Saturday and Sunday compared to Monday through Friday. The ROG-to-NO_x ratio increase is enhanced during the morning hours (6 a.m. to 9 a.m. and 9 a.m. to 12 p.m.).

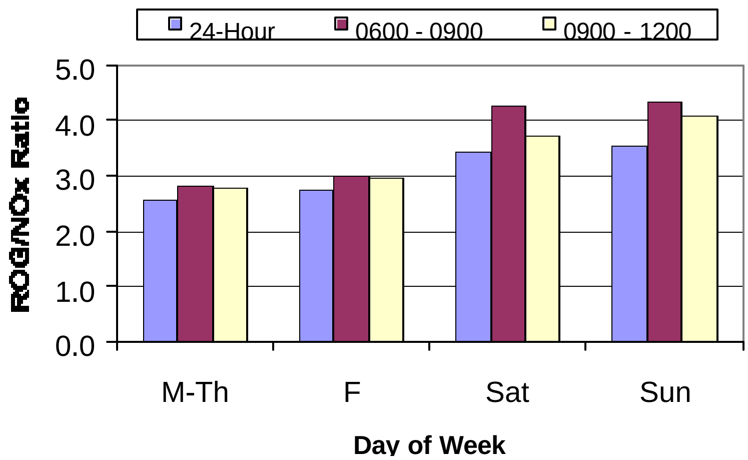


Figure 2-26. ROG/NO_x emissions molar ratios for year 2000 in the SoCAB.

As shown in **Figure 2-27**, although overall NO_x is less between 6 a.m. and 12 p.m. (noon) on weekends compared to weekdays, there is a relatively greater increase in NO_x emissions between 9 a.m. and 12 p.m. than 6 a.m. and 9 a.m. on weekends compared to weekdays. The increase is attributed, in part, to a delay in the morning peak activity of motor vehicles on weekends (see **Figure 2-28**).

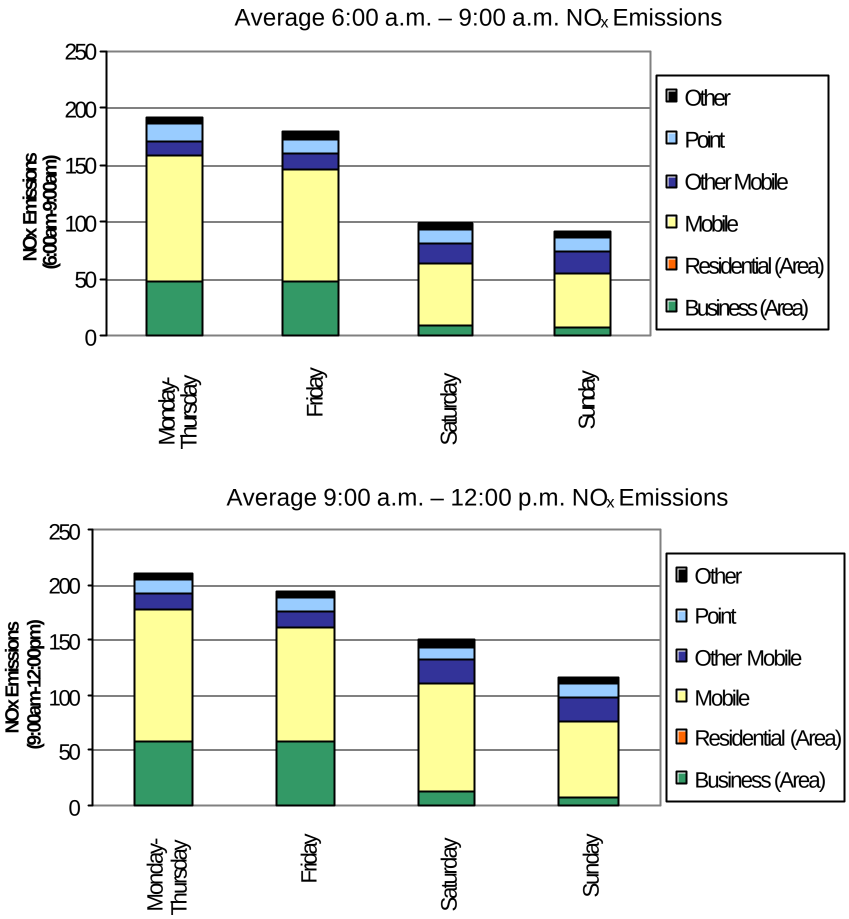


Figure 2-27. Relative increase in NO_x emissions from 9 a.m. to 12 p.m. is greater on Saturday and Sunday than on weekdays.

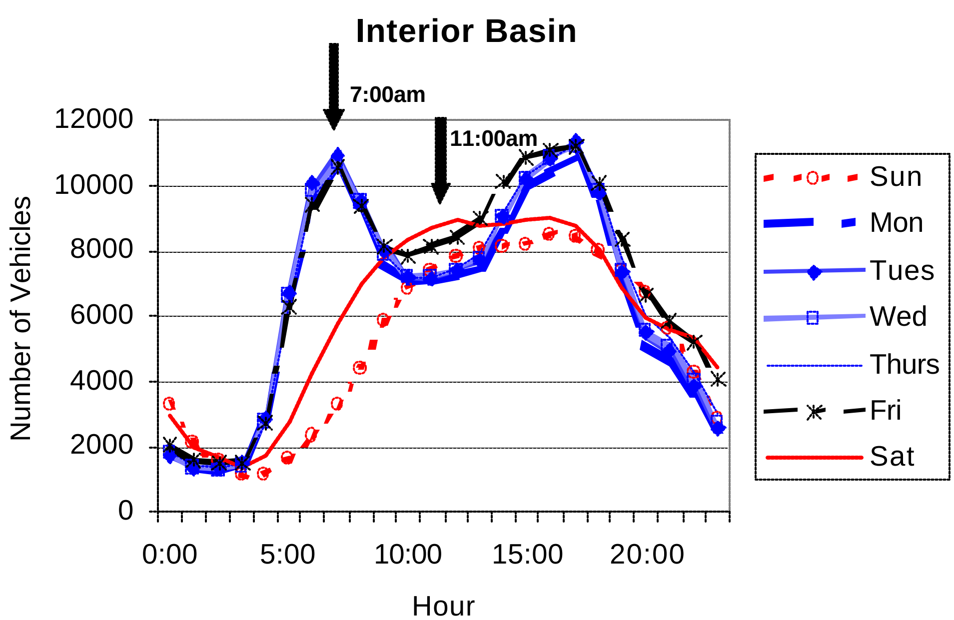


Figure 2-28. Morning peak of LDV activity is delayed on weekends.

Another timing-related effect hypothesized to contribute to higher weekend ozone concentrations is the difference in vehicle activity on Friday and Saturday evenings compared to other days. **Figure 2-29** shows that, on Friday, Saturday and Sunday from 8 p.m. to 12 a.m. (midnight), traffic volumes for LDV are slightly higher than on weekdays; **Figure 2-30** shows that HVD traffic volumes are lower than on weekdays. The net effect of increased evening LDV and decreased morning HDV traffic volumes on weekends is negligible.

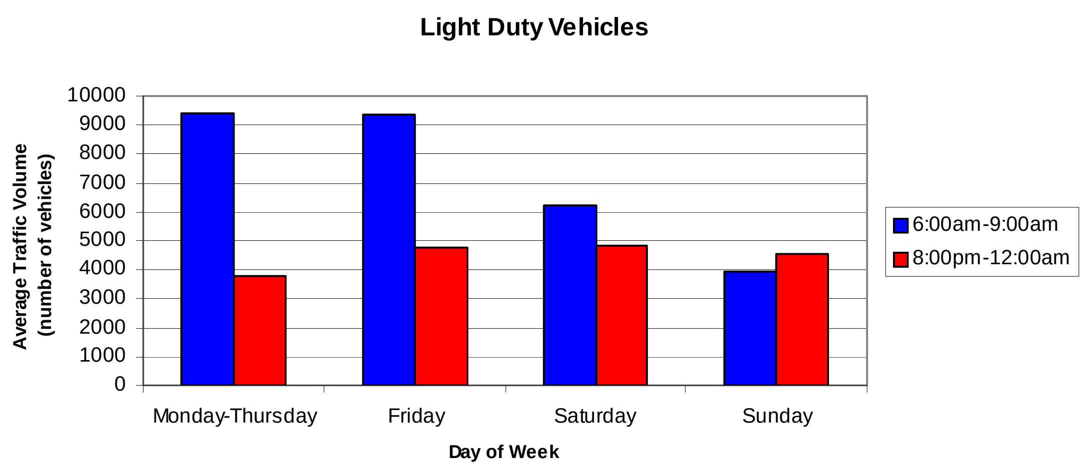


Figure 2-29. On Friday, Saturday, and Sunday from 8 p.m. to 12:00 a.m., LDV traffic volumes are higher than on weekdays.

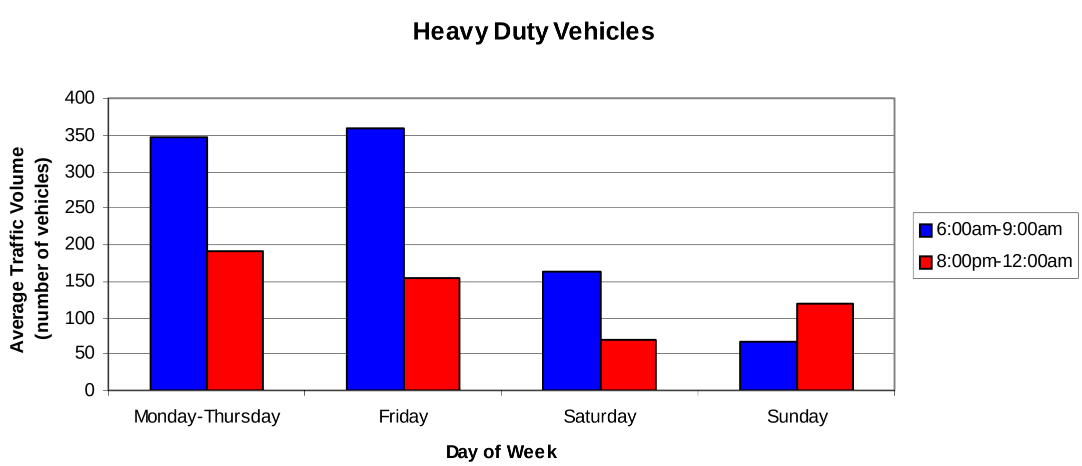


Figure 2-30. On Friday, Saturday, and Sunday from 8:00 p.m. to 12:00 a.m., HDV traffic volumes are lower than on weekdays.

The combination of predicted emission magnitudes and emissions ratios provides insight into potential future-year ozone concentrations. For example, applying the day-of-week and time-of-day activity variations developed in this study to future-year emission forecasts by the CARB for 2010 results in a prediction of ozone precursor emissions on weekdays in 2010 comparable to those on weekends in 2000 (see **Figure 2-31** and Appendix I), which in turn suggests the possibility that weekday ozone in 2010 could still be comparable to weekday ozone in 2000. However, precise predictions of ozone concentrations from emissions changes is not possible without the use of comprehensive photochemical models.

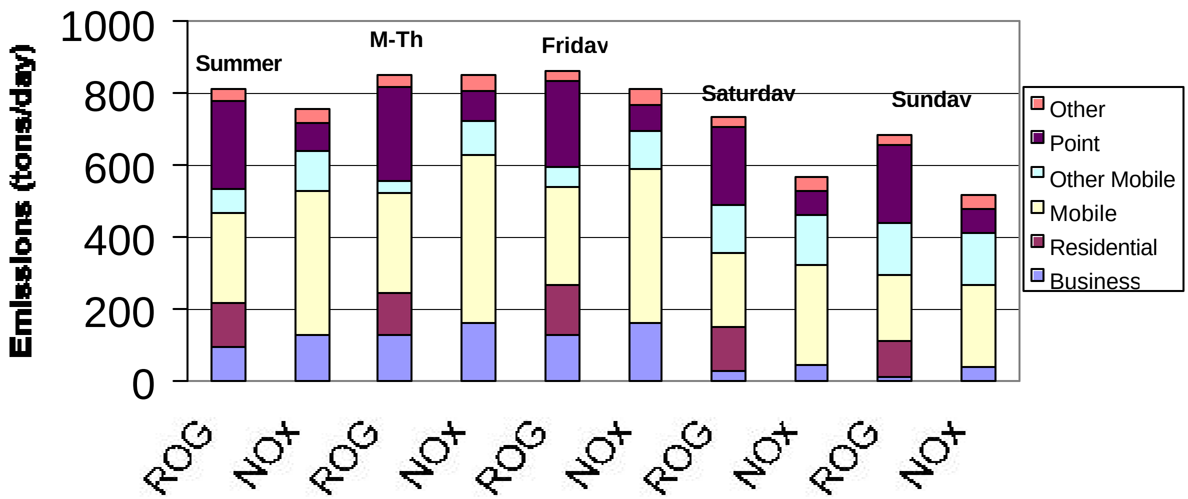


Figure 2-31. 2010 forecast day-of-week emissions in the SoCAB.

Because of high levels of NO_x emissions in the SoCAB, ozone production is hydrocarbon-limited even when NO_x emissions decrease on the weekends. Under these hydrocarbon-limited conditions, ozone production efficiency is a function of the ROG/NO_x ratio and, under the same meteorological conditions, ozone concentrations would be expected to increase as the ROG/NO_x ratio increases. Thus, higher ROG/NO_x ratios on weekends can result in higher ozone concentrations even though the total mass of emissions decreases.

The forecast of higher ratios in 2010 suggests that weekday and weekend ozone concentrations might be even higher in future years unless the levels of NO_x control are large enough to change the atmosphere in the SoCAB to a NO_x-limited regime. Continuing the analysis, the forecast emissions by day-of-week can be used to forecast ROG-to-NO_x emissions molar ratios. **Figure 2-32** shows the forecast ratios for 2010 for the SoCAB. As in year 2000, ROG/NO_x ratios increase on the weekends. But perhaps even more importantly, ROG/NO_x ratios are forecast to increase on all types of days in 2010.

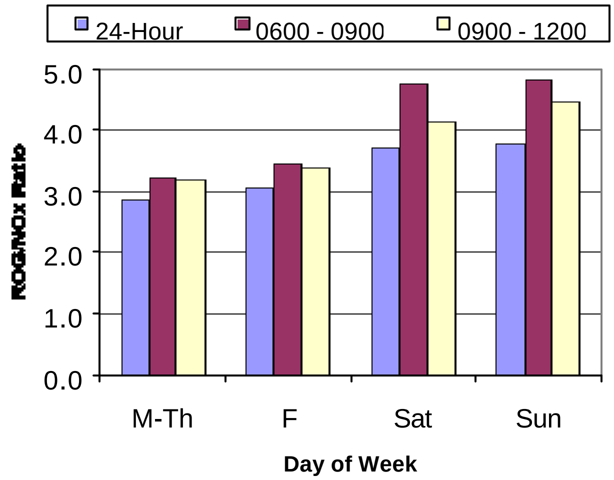


Figure 2-32. 2010 forecast ROG/NO_x emissions molar ratios for the SoCAB.

Another point of interest is a forecasted change in the source categories that are the largest contributors to ozone precursor emissions in the year 2010. A comparison of the emissions in Figures 2-31 with those in Figure 2-23 shows that predicted reductions in mobile source emissions mean that point sources, residential sources, and other mobile sources will become more important contributors in the future.

This finding should be understood in the context of CARB's and EPA's consistent efforts over the years to produce new on-road mobile emissions modeling tools that uniformly increase base-year emissions with each successive emissions model version. This trend continues to the present day. EMFAC-2000 (used in this study) estimates year 2000 emissions to be between 18% to 56% higher than emissions predicted by EMFAC-7G (California Air Resources Board, 2000). Similarly, the January 2002 version of MOBILE6 estimates significantly higher near-term emissions compared to its predecessor version, MOBILE5 (Beardsley, 2001). Thus lower ROG and NO_x mobile source emissions in 2010 may potentially be revised upward in the future.

Historically, mobile source emission modeling tools have tended to under-predict on-road motor vehicle emissions. The under-prediction problem is well-documented in various publications (e.g., see: National Research Council, 2000; U.S. Environmental Protection Agency, 1995; National Research Council, 1992; U.S. Environmental Protection Agency, 1992; Lawson et al., 1990; Pierson et al., 1990). Both the CARB and the EPA have attempted to correct modeling problems with various model updates over the years. For example, following the release of MOBILE1 in 1978, EPA released seven subsequent versions over the next 22 years (e.g., see National Research Council, 2000; pp. 63-64). New EMFAC and MOBILE model versions have generally increased emissions estimates for a given geographic area and base year. Three factors are largely responsible for increased emissions estimates with each new model version.

- Improved vehicle activity assumptions generally increase emissions-related activities compared to previous model versions. For example, recent versions of EMFAC incorporate more daily engine starts compared to older models.

- Updated information concerning control measure effectiveness often reduces the emission reduction benefit attributable to control measures. For example, MOBILE6 credits vehicle inspection and maintenance (IM) programs with less benefit than MOBILE5.
- Increased technical insights continue to identify new on-road emissions-producing activities and sources. Examples of past insights include identification of high-emitting vehicles as a disproportionate contributor to emissions, the contribution of evaporative losses to hydrocarbon inventories, and documentation of "aggressive driving" and its role in increased emissions.

2.5 OVERALL CONCLUSIONS

Observations of daily activities and common sense suggest that aggregate variations in human activities, which follow a weekend-weekday pattern, cause observable differences in weekend-weekday air quality, specifically ozone precursor emissions, and therefore, ambient ozone levels. The principal emphasis of STI's investigation of possible causes of the weekend ozone effect was on emissions activity data collection and analysis. In Phase II of this effort, we collected activity data for several emission source categories and subcategories. In this report, we have summarized the data collection efforts and analyzed the resulting activity data to obtain real-world estimates of the activity variations by day of week for major emission source categories in the SoCAB. We made the following observations:

- Combining emission changes for all categories (including off-road categories) by day of week results in an estimate that total 2000 ROG and NOx emissions in the SoCAB on weekends in the summer decline by about 12 to 18% and 35 to 41% on Saturdays and Sundays, respectively, relative to weekdays. These changes in emissions result in an increase of the ROG to NO_x ratio of more than 30% on weekends.[1]

These overall observations are supported by the following conclusions:

- A survey of business activity showed that business activity declined substantially on weekends (by up to 80%).
- A survey of residential activity showed that some residential activity increased substantially on weekends.
- In the urban areas of the SoCAB, surface street traffic volumes (which were dominated by light-duty vehicles) showed that traffic was reduced by about 15-30% on weekends and tended to peak around midday rather than during the morning and afternoon rush hours as on weekdays.

[1] It is noted that aircraft, trains, ships, and some miscellaneous categories for which no new or existing WD/WE activity data were acquired (about 4% of total ROG and 12% of total NOx emission) were treated as emitting the same amount on weekdays and weekends. If the weekday activity is substantially higher than weekend activity, weekend total NOx emissions would be somewhat lower than calculated in this study, resulting in a further increase of the ROG/NO_x emissions ratio on weekends of even more than 30%.

- Freeway traffic volume information showed that truck and bus activities decreased by up to 80%. On weekends in areas just beyond the urban zones, daily traffic volumes increased somewhat on weekends and tended to peak on Friday and Sunday late afternoons.
- Major point source NO_x emissions on Friday, Saturday, and Sunday were 8-18% lower, on average, than on Monday through Thursday. Note: if point source ROG reductions on weekends are proportional to NO_x reductions[2] (not proven in this study), day-of-week variations in point source ROG emissions could also play a significant role in the weekend ozone effect since point source emissions comprise 20% of ROG emissions.
- In year 2000, the single largest contributor to emission changes on the weekends is a substantial decline in heavy-duty truck traffic (representing 25% of all NO_x emissions on weekdays and 12 to 15% of all NO_x emissions on weekends).
- ROG emissions from recreational boats on Sunday are higher than from automobiles (see Appendices H and I). This does not seem likely. Because the weekday/weekend activity data for recreational boats appears reasonable, we believe the summer 2000 ROG inventory for recreational boats may be too high and recommend further study of this issue.
- Weekday/weekend off-road emissions were modeled using Lawn and Garden and Business IC Engine activity data. These 2000 ROG and NO_x emissions in the summer decline on weekends by 41 to 64% and 72 to 78% on Saturdays and Sundays, respectively, relative to weekdays. Note that day-of-week patterns of off-road engine use, other than lawn and garden equipment, are uncertain because the limited data collected during the business portion of the survey may not represent the proper distribution of off-road IC engines.
- Although projecting emission inventories into the future is quite uncertain, application of day-of-week patterns to future-year published emission inventories suggests that because of predicted increases of the HC/NO_x ratio in emissions, ozone concentrations in the future may not decline despite predicted decreases in emissions.

[2] ROG and NO_x are not necessarily produced by the same industrial processes.

3. METEOROLOGICAL EFFECTS

To better understand day-of-week effects on emissions and ozone precursors through observational approaches, it is important to account for the influence of weather. Meteorology can influence pollutant concentrations by horizontal and vertical transport, dispersion, and altered chemical reaction rates. Chemical reaction rates can be altered by changes in temperature, humidity, and solar radiation. Although it has previously been shown that the weekend ozone effect is not attributable to meteorology, this section reports on efforts to determine if there were differences in the day-to-day meteorology, which could have affected ozone precursors and emissions activities during the field study period (i.e., September 30 through October 9, 2000). It also presents evidence that shows which weekend days are meteorologically similar to which weekdays in order to allow a comparison of emission and ozone precursor concentrations on identified days independent of meteorology. Lastly, this section provides a brief overview of the meteorology during the SCOS97 ozone episode week of August 4 to 7, 1997, that is being studied by the CRC through proximate modeling techniques to assess the weekend effect.

Although weather conditions during the 2000 field study period were generally not favorable for high ozone and ozone precursor concentrations, this did not affect study results because the study was emissions-based. The highest ozone day in the study period was Sunday, October 1. Nevertheless, qualitative analyses of day-to-day variations in meteorological conditions showed that each weekend day had a reasonably similar meteorological weekday companion. Although not precisely the same, the days with similar meteorology provide an opportunity to minimize the influence of meteorology on day-to-day variations in emissions activity and ozone precursor concentrations in modeling. For the August 1997 episode, we found that the four-day period had generally similar meteorology (e.g., similarly high 500-mb heights, warm 850-mb temperatures, and high cap strength) typical of historic high ozone days in the SoCAB. However, there were important day-to-day differences that should be accounted for if the days are to be used to simulate weekend effects.

3.1 DATA SOURCES AND METHODS

We obtained meteorological data from a variety of sources in both electronic and paper formats. The data sources and the qualitative uses of each parameter are listed in **Table 3-1**.

Table 3-1. Sources and use of meteorological data.

Meteorological Parameter	Qualitative Use	Data Source
Upper-level synoptic pattern and 500-mb heights and precipitation	Overall weather pattern, and vertical and horizontal mixing	NOAA/NWS/NCEP Daily Weather Maps
850-mb temperatures	Vertical mixing	850-mb maps created using NOAA ARL's HYSPLIT 4 trajectory model with Eta Data Assimilation System (EDAS) data
Inversion cap strength	Vertical mixing	University of Wyoming (Sept. 2001) http://weather.uwyo.edu/upperair/sounding.htm
Precipitation	Enhanced dispersion and deposition	National Weather Service Office-Oxnard http://www.nwsla.noaa.gov/climate/climate.htm National Weather Service Office-San Diego http://www.wrh.noaa.gov/sandiego/climate.htm
Maximum and minimum temperature	Vertical mixing	National Weather Service Office-Oxnard http://www.nwsla.noaa.gov/climate/climate.htm National Weather Service Office-San Diego http://www.wrh.noaa.gov/sandiego/climate.htm
AM/PM surface air flow	Horizontal transport and dispersion	California Air Resources Board (Sept. 2001)
24-hr and 72-hr back-trajectories	Horizontal transport and dispersion	Created using NOAA-ARL's HYSPLIT 4 trajectory model with Eta Data Assimilation System (EDAS) data

Using the data listed in Table 3-1, for each day, eleven meteorological parameters related to horizontal and vertical dispersion characteristics were subjectively compared and days with similar meteorological conditions were grouped. In addition to this grouping, a somewhat independent grouping of the days was performed to provide more confidence in the results. In particular, a qualitative threshold was assigned to each meteorological parameter for each day to account for the probable effects of each parameter on pollutant concentrations, i.e., minus (–) implies that the weather patterns are not favorable for high ozone precursor concentrations while plus (+) implies that conditions are favorable for high ozone precursor concentrations, and zero (0) implies that a neutral impact was determined from the theoretical influence of the parameter on ozone formation or pollutant concentrations. For example, the presence of a low-pressure trough aloft is indicative of enhanced vertical mixing and possibly increased cloudiness, which is associated with lower pollutant concentrations and (–) would be assigned to this parameter for this day. The total concentration effects were then determined by summing the number of negative (–), positive (+), and neutral (0) influences that each meteorological variable would have had on ozone precursor concentrations. The day groups from the subjective review and the concentration effects were then compared. A discussion of the results is contained in Subsection 3.2.

To address the potential influence of horizontal airflow on pollutant concentrations, back-trajectories were prepared. For each day, 50-m, 300-m, and 1000-m agl back-trajectories were created using the National Oceanic and Atmospheric Administration Air Resources Laboratory's (NOAA-ARL) HYSPLIT 4 trajectory model with Eta Data Assimilation System (EDAS) data. These back-trajectories were used to estimate the paths of air parcels and indicate the possible regions from which emissions were being transported. The three levels were chosen to capture the different wind flows that can occur at various heights within the daytime mixing layer. The back-trajectories were run from 1000 PST back 24 hours and 72 hours with origins of Long Beach and Riverside. It is important to note that because of the coarse grid resolution of the EDAS data (40 km), the EDAS back-trajectories do not represent exact air parcel movement. However, these back-trajectories can be used as an indication of the general direction and distance that the air parcels traveled and a measure of transport and dispersion potential.

In addition to back trajectories, analyses of wind flow prepared by the California Air Resources Board (California Air Resources Board, 1984) were examined. The CARB prepares wind streamlines several times daily. These streamlines are then classified by the CARB based on wind direction and wind speed into specific flow types. The flow types can then be used to categorize the overall airflow pattern and assess the potential influence of air parcel movement on pollutant concentrations, origins and transport. The CARB flow types include onshore southerly (OS), sea breeze (SB), light and variable (LV), and light sea breeze (LSB). We looked at both the morning and afternoon flow types.

To address the potential influence of vertical transport and dispersion on pollutant concentrations, 850-mb temperatures at 0400 PST were used to estimate inversion strength. Low 850-mb temperatures tend to be associated with weaker inversions and enhanced vertical dispersion. Warmer 850-mb temperatures are generally associated with shallower inversions, which can cause pollutant concentrations to be increased. The 850-mb temperatures were also used to determine the “inversion cap strength” for each day. The higher inversion cap strength the more likely the inversion is to stay intact for the entire day and allow for higher pollutant concentration buildup. Days with high ozone concentrations are typically found to be associated with cap strengths of 18°C to 25°C. The difference between the maximum and minimum temperatures at Los Angeles (downtown) and Riverside was also used an indicator of inversion strength. The higher the difference, the more likely is the presence of a stronger inversion.

3.2 RESULTS

Table 3-2 summarizes the results of the qualitative analyses of the meteorology on each of the field study days. Examining the table shows that there were day-to-day differences in the meteorology during the field study that could influence pollutant concentrations. However, there were days with sufficiently similar meteorology to make valid weekday/weekend ozone precursor concentration comparisons. Comparison of the meteorology on Sunday, October 1 and Monday, October 2 (highlighted in Table 3-2) serves as an example. Both days had similar positive influences on concentrations (e.g., higher 500-mb heights, warmer 850-mb temperatures, higher cap strength, and lower wind speeds). Neither day experienced any precipitation. Other meteorological parameters were judged, for the most part, to be neutral or slight negatives, resulting in total scores of zero and +2, respectively.

Table 3-2. Chart summarizing the meteorological data and the probable effect on pollutant concentrations.

Conc. Effect	1200 UTC 500 mb Height (dm)	Conc. Effect	12 Z 850 Temps	Conc. Effect	Inversion (CAP) Strength	Conc. Effect	Precipitation (inches)	Conc. Effect	AM Sfc Flow (1800 UTC)	Conc. Effect	PM Sfc Flow	Conc. Effect	Riverside Trajectory	Conc. Effect	Long Beach Trajectory	Conc. Effect	LA Max temp	LA Max-min	Conc. Effect	LA Avg Max Temp	LA Avg Min Temp	LA Avg Max-Min	RX Max temp	RX Max-min	Conc. Effect	RX Avg Max Temp	RX Avg Min Temp	RX Avg Max-min
+	580						0	0	33 % OS 29% SB	-	20% OS 67% SB	-																
-	580	0	15	-	9.6	-	Trace	-	SB	-	OS	-	Short Distance 12 Hour Recirculation No stagnation	+	W/NW morning stagnation	+	77	15	-	81	63	18	N/A	N/A		88	55	33
-	580	0	21	+	15.2	+	Trace	-	SB	-	SB	-	NE/E moderate	-	NE/E moderate	-	N/A	N/A		81	63	18	80	24	-	88	54	34
-	583	+	22	+	14.1	+	0	0	SB	-	N/A		SE/E light	+	E moderate (300 m stagnant)	-	75	14	-	81	63	18	88	32	0	88	54	34
0	584	+	21	+	16.1	+	0	0	SB	-	SB	-	W light-near stagnation early morning	+	W light to moderate	+	78	14	-	81	63	18	89	32	0	86	54	32
+	583	+	19	0	14.5	+	Trace	-	OS	-	SB	-	W moderate-near stagnation early morning	+	W moderate-early morning stagnation	+	74	12	-	81	63	18	80	22	-	86	54	32
-	576	-	14	-	13.1	0	Trace - 0.03	-	OS	-	SB	-	E/SE moderate	-	W/SW moderate-light morning	+	71	8	-	81	62	19	70	10	-	87	53	34
-	580	0	20	+	14.2	+	0	0	SB	-	SB	-	E moderate to strong	-	NW moderate	-	75	10	-	81	62	19	82	25	-	87	53	34
-	581	+	18	0	13.1	0	Trace to 0.03	-	SB	-	SB	-	E moderate	-	W light-near stagnant morning	+	67	4	-	81	62	19	70	8	-	87	53	34
-	580	0	14	-	11.5	-	Trace to south	-	OS	-	SB	-	NW/W moderate	-	NW moderate	-	73	8	-	81	62	19	74	12	-	86	54	32
0	580	0	17	0	14.4	+	0.01	-	LV	+	SB	-	N stagnation	+	N stagnation	+	73	14	-	81	62	19	79	22	-	85	53	32
+	580	0	18	0	12.3	-	Trace	-	LSB	0	OS	-	S very stagnant	+	Variable light	+	72	12	-	80	62	18	77	22	-	85	53	32
-	578	-	N/A	N/A	6.5	-	0.02	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	69	9	-	80	62	18	69	12	-	84	52	32

A summary of days with similar meteorology, which also had similar concentration effect scores, is shown in **Table 3-3.** The results show that for every weekend day, a reasonably comparable weekday existed. For example, Sunday, October 1, and Monday, October 2, were days with similar meteorology; they had the most positive concentration effects and relatively high observed ozone concentrations (**Figure 3-1)**. Figure 3-1 shows the 8-hr peak ozone for each day during the study period. Wednesday, October 4, and Saturday, October 7, also had similar meteorology; they had the most negative concentration effects and low observed ozone concentrations (Figure 3-1).

Table 3-3. Summary of probable effects of meteorology on pollutant concentrations. Minus (–) implies that the weather patterns are not favorable for high ozone precursor concentrations while plus (+) implies that conditions are favorable for high ozone precursor concentrations. Matched days are those with similar meteorology and concentration effects.

Day of Week	Date	- Conc. Effects	0 Conc. Effects	+ Conc. Effects
Sat	9/30/00	7	1	2
Thu	10/5/00	7	2	2
Sun	10/1/00	4	2	4
Mon	10/2/00	3	3	5
Wed	10/4/00	9	1	1
Sat	10/7/00	10	1	0
Sun	10/8/00	4	3	4
Mon	10/9/00	5	3	3

Even though days with similar meteorology occurred during this period, it should be noted that this time period was not particularly favorable for high ozone concentrations. Precipitation was recorded on eight of the eleven study days. As further evidence of probable stronger than usual vertical mixing, inversion cap strengths during the study were 6.5°C to 16.1°C; typically, cap strengths of more than 18°C are associated with high ozone concentrations. The highest ozone levels of the period occurred on October 1 (Sunday) just east of Riverside, with a cap strength of 14.1° C. October 1 was also one of the two warmest days of the period at Riverside.

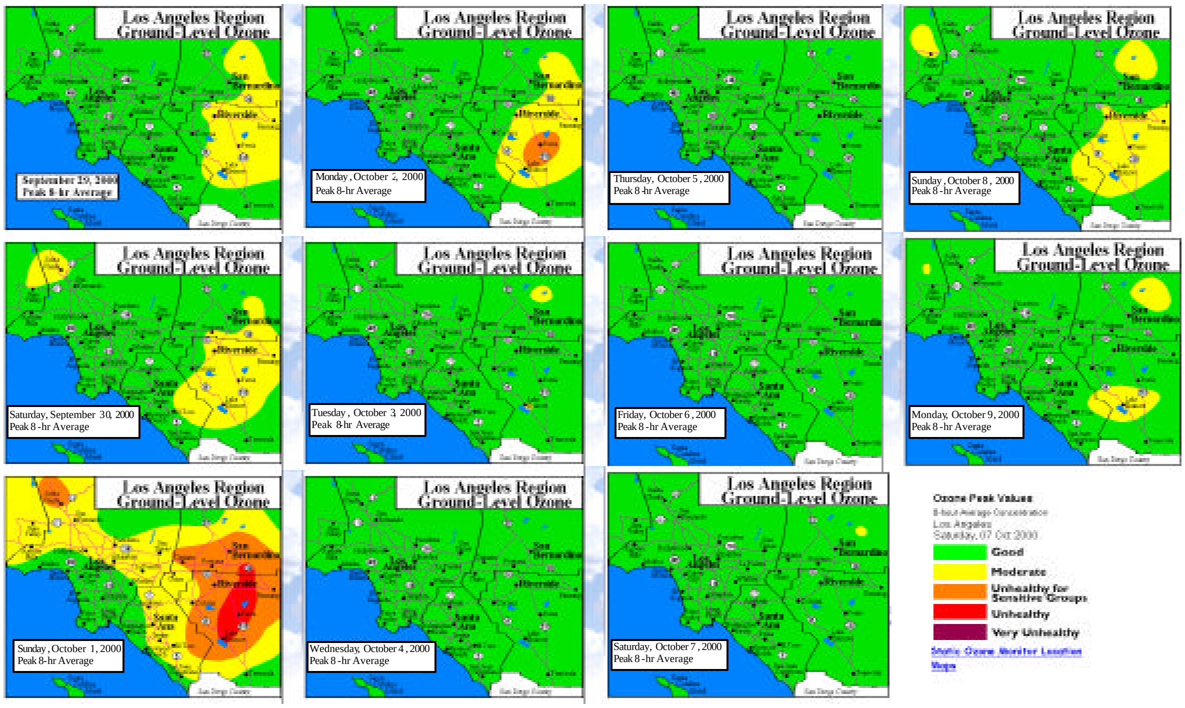


Figure 3-1. Southern California 8-hr peak ozone concentrations for each study day.

3.3 SCOS97 EPISODE METEOROLOGY

The Southern California Ozone Study, an intensive field study, was conducted during summer 1997. The objective was to collect data to improve the understanding of ozone formation and transport in southern California. One particularly high ozone episode period (Monday, August 4 through Thursday, August 7, 1997) became the focus of the data analyses of the SCOS97. For the purposes of estimating possible weekend ozone effects, CRC is sponsoring proximate ozone modeling using these data. In this section, we provide a summary of the meteorology on these days and make recommendations about the use of these days in weekend-effect modeling.

The meteorology for each of the August days was examined in the same detail as the late-summer 2000 episode discussed above. The data used included 500-mb heights, 850-mb temperatures, inversion cap strength, CARB wind flow types, surface temperatures, EDAS modeled wind fields, CALMET wind fields and back-trajectories, and mixing heights estimated from temperature and radar profiler reflectivity data collected at 26 sites during SCOS97. The mixing height data were processed and averaged to represent the mixing heights in four geographic zones (e.g., coastal, western SoCAB, eastern SoCAB, and inland desert).

The four-day period had generally similar meteorology (e.g., similarly high 500-mb heights, warm 850-mb temperatures, and high cap strength) typical of historic high ozone days in the SoCAB. However, there were important day-to-day differences that should be accounted for if the days are to be used to simulate weekend effects. There were substantial day-to-day differences in horizontal transport patterns and vertical mixing as listed in **Table 3-4**.

Table 3-4. Winds and afternoon mixing heights during the August 1997 episode.

Date	Day of Week	AM Winds	PM Winds	Afternoon Mixing Heights (m agl)			
August 1997				Coastal	West Basin	East Basin	Desert
4	Monday	S/SE	W	500	400	1200	2600
5	Tuesday	E	W	400	400	1200	3500
6	Wednesday	variable	S	300	500	1300	2600
7	Thursday	S	S	400	700	700	1400

If consecutive meteorological data as it occurs in real-time are used in air quality modeling, with emissions altered to estimate weekend effects, it is important to recognize the potential impacts on modeling results of the real-time variations in meteorology. If the four-day period is treated not as Monday through Thursday, but as Thursday through Sunday, or Friday through Monday, it is likely that some of the predicted changes in ozone from the computer simulations will be in large part due to changes in meteorology and not emissions. Meteorological changes account for considerably lower mixing heights in the eastern basin and desert and a higher mixing height in the western basin on the fourth day of the episode. In addition, the wind flow patterns varied substantially from day to day.

4. WEEKDAY/WEEKEND TRENDS IN HYDROCARBONS

This section contains a series of individual analyses of hydrocarbon concentrations and composition differences by day of week. The synthesis of these analyses with the work performed in other tasks (presented in Sections 2 and 3) and with DRI will be presented in the combined Phase III report.

Three appendices to this section were prepared. Appendix J contains the data validation results, and Appendices K and L contain plots that further support the findings presented.

4.1 INTRODUCTION

4.1.1 Overview

Volatile organic compounds (VOCs) are important precursors to ozone. By understanding the temporal and spatial characteristics of VOCs, one can gain insight into likely VOC emission sources and, thus, which sources to control in order to assist in reducing ozone concentrations. For this project, understanding the spatial and temporal characteristics of the VOCs may help support our understanding of the weekday/weekend ozone effect.

Hydrocarbon data collected as part of the Photochemical Assessment Monitoring Stations (PAMS) network were extensively used in our analysis. The PAMS network typically monitors 56 target hydrocarbons and two carbonyl compounds, ozone, oxides of nitrogen (NO_x and/or NO_y), and meteorological measurements (U.S. Environmental Protection Agency, 2001). The number and type of PAMS sites varies among metropolitan statistical areas (MSAs). Ozone precursors (VOC and NO_x) and surface meteorology are required to be measured at two to five sites in an MSA, depending on the MSA population. Different site types have different measurement objectives (**Figure 4-1**):

- Type 1 - Upwind and background characterization site. Type 1 sites are intended to characterize upwind background and transported ozone and its precursor concentrations entering the area.
- Type 2 - Maximum ozone precursor emissions impact site. Type 2 sites are intended to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions representative of the MSA (or consolidated MSA) are expected to impact. These sites are also referred to as urban or urban center sites.
- Type 3 - Maximum ozone concentration site. Type 3 sites are intended to monitor maximum ozone concentrations occurring downwind from the area of maximum precursor emissions.
- Type 4 - Extreme downwind monitoring site. Type 4 sites are intended to characterize the extreme downwind transported ozone and its precursor concentrations exiting the area.

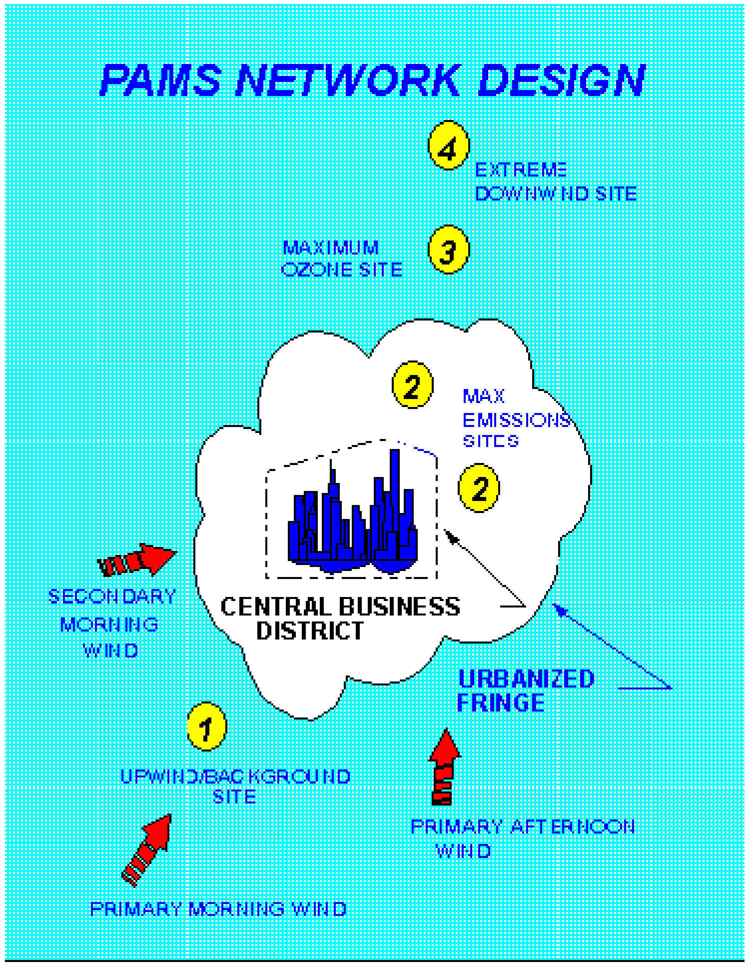


Figure 4-1. PAMS network design as described by the EPA (U.S. Environmental Protection Agency, 2001). PAMS site Types 1 through 4 are shown here and described in the text.

Most of the VOCs identified as part of PAMS are significant components in gasoline evaporative or gasoline combustion (exhaust) emissions (**Table 4-1**).[3] While a few species have other significant sources in the Los Angeles basin, clearly gasoline vehicle emissions dominate. Based on the dominance of this source on the ambient VOCs as measured by PAMS, and on previous characterization of the VOC data in the basin (e.g., Fujita et al., 1992; Main et al., 1999a; Main et al., 1999b), the following observations are expected with respect to the temporal and spatial variation in VOC concentrations:

- Motor vehicle emissions are the most likely source of most of the PAMS VOCs. Strong correlations have been observed among the PAMS target species in the SoCAB indicating a common source, and most of the species point to motor vehicle emissions as their source.

[3] Unfortunately, the PAMS species list does not help in identifying diesel emissions.

- Fresh emissions impact the sites all day. The composition remains relatively unchanged with time of day at the urban core sites.
- Evaporative components (e.g., butanes, pentanes) are a higher portion of the total VOC during midday when temperatures are highest.
- Photochemically produced species (e.g., formaldehyde) have higher concentrations midday.
- Isoprene concentrations are low at night and higher midday consistent with biogenic emission patterns. Isoprene does not correlate with anthropogenic hydrocarbons.
- Photochemically reactive species (e.g., xylenes) are depleted relative to less reactive species midday (e.g., benzene).
- The data collected at the downwind (Banning) site is consistent with well-aged air in which less reactive hydrocarbons accumulate (e.g., ethane, propane). Most of the samples collected at Hawthorne are also indicative of well-aged air. Hawthorne is considered an upwind site to the rest of the SoCAB and as such receives aged air parcels from offshore.

Given this understanding of the VOC data, while gasoline vehicle activity may change with day of week, we do not expect to see changes in the VOC composition (normalized species concentrations) as a function of the day of week.

4.1.2 Objectives

As a part of the WD/WE effect analysis, the following investigations were performed:

1. Have historical PAMS data indicated a pattern by day of week? What are day-of-week trends in speciation (concentration, weight percent, and reactivity-weighting) at PAMS sites? Are these trends statistically significant?
2. How did the special studies data collected at the Los Angeles N. Main PAMS site in October 2000 compare with data collected in previous years at the same site? Did the composition or concentration data collected during the field study time period differ significantly from the historical data?
3. How did special study canister samples collected by DRI near Los Angeles N. Main compare to speciation at the PAMS-like site?
4. Were there day-of-week differences in speciation during the field study?

In the combined DRI/STI Phase III synthesis report, we will relate the findings to the above questions to the findings in emissions activity. Ultimately, we are trying to determine whether the study period VOC data were unusual compared to that of previous years. Then, if the data were not unusual, we want to determine if there were significant differences by day of week in composition and whether these differences relate to known changes in activity.

Table 4-1. Key PAMS species and their major sources.

Species	Major Sources	Comments
Ethene	Motor vehicle exhaust, petrochemical industry	Tracer for vehicle exhaust
Acetylene	Motor vehicle exhaust, combustion processes	Tracer for vehicle exhaust. More abundant in gasoline than diesel exhaust
Ethane	Natural gas use	Non-reactive; accumulates in the atmosphere
Propene	Refinery, chemical manufacturing, vehicle exhaust	More abundant in diesel than gasoline exhaust
Propane	LPG and natural gas use, oil and gas production	Relatively non-reactive. Also more abundant in diesel than gasoline exhaust; accumulates in the atmosphere
i-butane	Consumer products, gasoline evaporative emissions, refining	Used as replacement of CFCs in consumer products
Butene	Motor vehicle exhaust	More abundant in gasoline than diesel exhaust. A thermal decomposition product of MTBE
n-butane	Gasoline evaporative emission	Tracer of gasoline use
t-2-butene	Motor vehicle exhaust	Enriched in evaporated gasoline relative to exhaust
i-pentane	Solvent use, refining, mobile sources	Among most abundant species in urban air. More abundant in gasoline than diesel exhaust
n-pentane	Motor vehicle exhaust, gasoline evaporative emissions	Enriched in evaporative emissions relative to exhaust
Isoprene	Biogenic	Tracer of biogenic emissions; reactive
Internal olefins (e.g., t-2-pentene)	Gasoline evaporative emissions, plastics production	Reactive
2,2-dimethylbutane	Motor vehicle exhaust	More abundant in diesel than gasoline exhaust
Benzene	Motor vehicle exhaust, combustion processes, refining	Tracer for vehicle exhaust; significantly reduced since 1995 with the introduction of reformulated gasoline
2-methylhexane	Motor vehicle exhaust	More abundant in gasoline than diesel exhaust
2,2,4-trimethylpentane	Gasoline evaporative emissions	Also in motor vehicle exhaust
n-heptane	Surface coatings, degreasing	Also in motor vehicle exhaust
Toluene	Solvent use, refining, mobile sources	Among most abundant species in urban air
Styrene	Solvent use, chemical manufacturing	Also in motor vehicle exhaust
Heptane and octane isomers	Oil and gas production, asphalt, gasoline	Also in motor vehicle exhaust
n-nonane	Dry cleaning, degreasing vehicles	Also in motor vehicle exhaust
Xylenes	Solvent use, refining, motor vehicles	Reactive
n-decane, undecane	Fuel storage, surface coatings	More abundant in diesel than gasoline exhaust
Formaldehyde	Fuel combustion	Also photochemical reaction products

4.2 AVAILABLE DATA AND DATA VALIDATION SUMMARY

4.2.1 Data Availability

Table 4-2 lists the surface hydrocarbon and carbonyl compound data available from Southern California PAMS and PAMS-like sites for 1999 and 2000. (The data for 1994 through 1997 were previously summarized by Main et al., 1999a). Although we also obtained the 1998 data, we did not include the data in this analysis in order to focus on the most recent two years. The data were retrieved from the EPA's Aerometric Information Retrieval System (AIRS). Eight 3-hr samples are collected daily at Pico Rivera while samples are collected every third day at other sites. Two 3-hr samples are collected daily at the Los Angeles N. Main PAMS-like site, part of a long-term trend network operated by the CARB. All other sites are PAMS and operated by the SCAQMD. In our data downloads, and repeated checking, we found that the total nonmethane organic compound (TNMOC) values were missing in AIRS for 2000 at Azusa, Banning, and Burbank.

We were also provided with the following VOC samples:

- Twenty 3-hr samples collected by the CARB at Los Angeles N. Main in cooperation with the October 2000 field study (September 30-October 8, 2000 at 0100, 0500, and 0800 PST).
- Sixty-three canister samples, averaging 0.75 hr each, collected by DRI in the mobile van during the field study.
- Twenty-one 3-hr canister samples collected by DRI at Azusa during the field study.
- One hundred sixty 1-hr samples collected by DRI at Azusa during the field study using the on-site auto-GC.

Table 4-2. Summary of available historical VOC data. PAMS samples were collected at 2300 (Day-1), 0200, 0500, 0800, 1100, 1400, 1700, and 2000 PST.

AIRS Code	City	Sampling Frequency	Lat	Lon	PAMS Site Type	1999	n	2000	n
060371601	Pico Rivera	3-hr, daily	34.0133	-118.0594	2	7/1-9/30	690	7/1-10/16	638
060370002	Azusa	3-hr, every 3rd day	34.1358	-117.9228	3	7/2-9/30	205	7/2-9/30	195
060650012	Banning	3-hr, every 3rd day	33.9222	-116.8583	4/1[a]	7/2-9/30	191	7/2-9/30	0[d]
060711004	Upland	3-hr, every 3rd day	34.0989	-117.6736	4/1[b]	6/25-9/30	215	7/2-9/30	199
060375001	Hawthorne	3-hr, every 3rd day	33.9306	-118.3689	1	7/2-9/30	188	7/11-9/30	173
060371002	Burbank	3-hr, daily	34.1764	-118.3161	1/2	7/1-9/30	557	7/1-10/5	424
060376002	Santa Clarita	3-hr, every 3rd day	34.2315	-118.3201	Suburban	7/5-9/30	199	8/16/-9/29	0[d]
060371103	Los Angeles N. Main[c]	3-hr, every 3rd day	34.0672	-118.2419	Urban	7/2-9/30	62	7/2-9/27	28

[a] In AIRS, Banning is listed as a Type 2 site. However, Main et al. (1999a) recommended that Banning be designated as a Type 4/1 site based on the concentration and composition data and known transport patterns in the basin.
[b] Upland data are more indicative of a Type 3 site (Main et al., 1999a).
[c] Los Angeles N. Main is not a PAMS site, but uses similar analytical methods and reports a similar list of VOCs. Samples were only collected at 0500 and 1200 PST in 1999 and 0500 PST in 2000.
[d] Only carbonyl samples were available via AIRS at time of download.

4.2.2 Validation Approach

Data validation is critical because serious errors in data analysis and modeling results can be caused by erroneous individual data values. This section summarizes our approach to validating VOC data. Guidelines for PAMS data validation are documented in the EPA PAMS data analysis workbook (Main and Roberts, 2000).

We used VOCDat to perform the VOC data validation. VOCDat, a software tool developed by STI, allows an analyst to display the VOC data collected with automatic gas chromatographs (auto-GCs) and canister systems, perform quality control (QC) tasks on the data, and begin data analysis (Main and Prouty, 2000). VOCDat displays data using scatter plots, fingerprint plots, and time-series plots.

- Scatter plots. We investigated the relationship among species using the following scatter plots: every species versus TNMOC; benzene versus toluene and acetylene; propane versus propene; ethene versus propene; i-butane versus n-butane; 2-methylpentane versus 3-methylpentane; m-&p-xylenes versus o-xylene; and n-pentane versus i-pentane. The scatterplots were used to look for correlations as well as outliers.
- Time-series plots. We investigated the concentrations of species in every sample over a specified time period. These plots were useful in showing the diurnal behavior of a species. Time-series plots of all species, plotting several species at a time, were inspected to find time periods and samples that warranted additional inspection.

- Fingerprint plots. We inspected the concentration of each species in a sample (in chromatographic order) to help identify unique characteristics of the samples. Every fingerprint was inspected with a focus on samples identified as "odd" in other plots or data screening.

Other features of VOCDat that facilitate data validation and data analysis include

- Computation of concentrations for species groups including unidentified hydrocarbons, sum of PAMS target species, aromatic hydrocarbons, olefins, paraffins, and carbonyl compounds.
- Computation and display of the weight percent of individual species.
- Computation of reactivity-weighted data. Concentration or weight percent data may be multiplied by the maximum incremental reactivity (MIR) scale developed by Carter (1991).[4]

We also used auto-screening facilities within VOCDat to prepare lists of data that failed to meet criteria. Three different screening tests were performed: abundant species concentrations, concentration comparisons/species relationships, and concentration variability as discussed next.

- At most PAMS urban sites across the United States (as opposed to remote sites), there is a common set of hydrocarbon species that are typically abundant including acetylene, ethane, propane, n-butane, i-pentane, n-pentane, benzene, toluene, and the xylenes. Experience shows that if most of these species are present at relatively high concentrations, e.g., above 1 ppbC, then all of these species should probably be present above the detection limit. We used the species listed in this paragraph in the screening.
- In addition to commonly present hydrocarbons, there are also relationships among the hydrocarbons that are apparent at many sites. VOCDat provides a check of several expected relationships. For example, all three xylene isomers [ortho (o-), meta (m-), and para (p-)] tend to be present in about equal concentrations at ambient sites in and near urban areas. Since the m- and p-xylenes typically coelute in most GC systems, the concentration of the sum of these two species should exceed the concentration of o-xylene. Thus, one check of the data might be to determine if o-xylene concentrations are greater than the sum of m- and p-xylenes. (Of course, there are always exceptions because there are sources of o-xylene independent of the other two isomers.) The default check of ethane concentrations less than 2 ppbC when benzene concentrations are greater than 2 ppbC derives from incidences where the cold trap failed causing low or zero concentrations of the C2 hydrocarbons while the C5+ species concentrations were normal. Ethane concentrations have been found at most sites to be above about 2 ppbC all the time.

[4] Incremental reactivity is defined as the change in ozone caused by adding an arbitrarily small amount of test hydrocarbon to the emissions in the episode, divided by the amount of test hydrocarbon added. The MIR scale provides an estimate of moles ozone formed per mole carbon of each organic species measured, where the ozone formation estimates are intended to be used in a relative, rather than absolute, manner. This scale is useful in data validation and analysis because a species that is present in relatively low concentration may be very reactive; the MIR-weighted data may indicate that this low concentration hydrocarbon is important.

- A third set of quality checks on the data includes a check of the sample concentrations that lie outside the majority of the sample population. It is useful to determine a list of "outliers" using statistics in order to provide a check independent of the graphical checks on the data. For this check, the abundant species (or species groups, TNMOC) concentrations can be compared to the overall sample population using the standard deviation. We performed this screening using the same species as used in the typically abundant screening test with the screening criteria set for four times the standard deviation.

VOCDat sorts through data and provides a list of samples that do not meet the criteria. No samples are altered or QC codes changed during this screening. We review the list of samples that fail to meet criteria and then investigate samples that appear odd.

Our strategy is to flag entire samples when there is a problem with two or more of typically abundant PAMS species[5] (e.g., toluene, i-pentane, i-butane, n-butane, benzene, acetylene, ethene, xylenes, and ethane). Individual species are flagged as suspect when there are problems noted and the concentration of the hydrocarbon is low compared to other species in the sample. Our approach is not to invalidate data, but rather to flag data as suspect that do not meet our conceptual model of hydrocarbon emissions, formation, and removal. We did not include flagged data in our analyses.

4.2.3 Validation Results

When we identified samples or individual species that needed to be flagged, we also entered a comment about why a QC code was changed. VOCDat retains a list of these comments and the changes to the QC codes. The tables in Appendix J list all samples we identified as suspect or invalid and provide the reason for the QC code change. In summary, from 0 to 50% of the data were flagged as suspect at each site. Highlights of our observations include the following:

- Very few samples were flagged as suspect in the Banning, Hawthorne, Los Angeles N. Main, Pico Rivera, Upland, and Santa Clarita data sets for 1999 and 2000.
- About half the samples for the Azusa 1999 data set were flagged as suspect while none of the 2000 samples were flagged. In general, the problems identified were related to low concentrations of some species relative to others including i-butane, n-butane, o-xylene, and ethylbenzene. Possible problems with the butane data could lead to problems in interpreting changes in evaporative emissions.
- About 20% of the Burbank data were flagged as suspect both in 1999 and 2000. Many of the 1999 Burbank samples were missing ethane and/or ethene data. There were also apparent problems with the xylenes data. In 2000, we noted problems with 2-methylpentane, 2,3-dimethylpentane, n-pentane, and 2,2,4-trimethylpentane indicating possible misidentification of these species.

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[5] Abundant species based on PAMS data analyses performed by STI with California, Texas, Georgia, mid-Atlantic, and Northeastern states data.

For CO, ozone, NO, and NO_x, we inspected distributions of concentrations as a function of time of day to investigate the diurnal profiles. The data at all sites appeared to fit expected diurnal patterns. We also computed NO_x based on the sum of $NO+NO_2$ and compared this sum to the reported NO_x as a check; no problems were noted.

4.3 DESCRIPTION OF SOCAB VOC DATA

4.3.1 Overview

We primarily used two types of plots to investigate the data: fingerprint plots and box-whisker plots. In box whisker plots (an example is shown in **Figure 4-2**[a]), the box shows the 25th, 50th (median), and 75th percentiles. The whiskers always end on a data point; so when the plots show no data points beyond the end of a whisker, the whisker shows the value of the highest or lowest data point. The whiskers have a maximum length equal to 1.5 times the length of the box (the interquartile range). If there are data outside this range, the points are shown on the plot and the whisker ends on the highest or lowest data point within the range of the whisker. The "outliers" are also further identified with asterisks representing the points that fall within three times the interquartile range from the end of the box and circles representing points beyond this. These plots are also useful for data validation.

Because we were also interested in how similar or dissimilar the data are among time periods, we used an option called a notched box-whisker plot to analyze data in this study (Figure 4-2[b]). These plots include notches that mark confidence intervals (C.I.). The boxes are notched (narrowed) at the median and return to full width at the 95% lower and upper confidence interval values. If the 95% confidence interval is beyond the 25th or 75th percentile, then the notches extend beyond the box (hence the "folded" appearance).

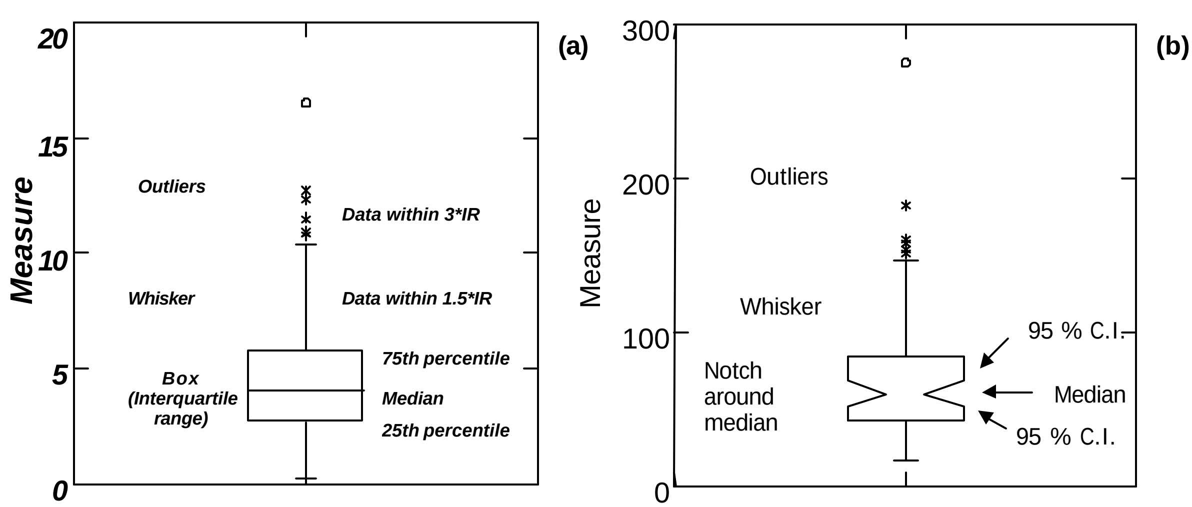

Figure 4-2. Illustration of (a) box-whisker plots and (b) notched box-whisker plots as defined by SYSTAT statistical software.

4.3.2 Overall Characterization of the Data

To establish a basis from which to proceed, we prepared several plots of the 1999 and 2000 data to investigate the overall characteristics including ranges in total concentrations, abundant species, and diurnal patterns in concentration and composition. We then compared these results to previous work.

Figure 4-3 shows the diurnal variation of TNMOC concentrations at all sites in 1999 and 2000 combined using notched box whisker plots. The following observations are made:

- TNMOC concentrations were generally lower midday than in the 0500 PST and 2300 PST samples. This temporal pattern is consistent with differences in mixing height between early morning/nighttime and midday (i.e., mixing heights are generally low at night and higher in the day allowing for more dilution of emissions).
- TNMOC concentrations were highest at Burbank and Pico Rivera where many samples had concentrations above 500 ppbC. Note that high concentration (>1000 ppbC) samples were also observed at Hawthorne and Azusa.
- The Azusa and Upland TNMOC concentrations were similar and exhibited similar diurnal patterns. TNMOC concentrations at Banning were lowest, with most concentrations less than 200 ppbC. This is consistent with the site's location far downwind. Santa Clarita concentrations fell between those of Azusa/Upland and Banning.
- High TNMOC concentrations at Hawthorne showed that nearby sources frequently influenced this site. Previous investigations (Main et al., 1999a) showed that the samples with greater than 1000 ppbC TNMOC had unidentified concentrations greater than 900 ppbC. Fingerprints of identified VOCs were similar between samples above and below 1000 ppbC TNMOC, indicating the sources contributed a non-PAMS target compound.
- Many samples at Hawthorne, Santa Clarita, Pico Rivera and Azusa had unidentified concentrations above 200 ppbC (Figure 4-4) indicative of complex mixtures of VOCs at the sites.
- The median unidentified mass ranged from 19% of the TNMOC at Los Angeles N. Main to 37% at Banning. The unidentified mass was 22% of the TNMOC at Pico Rivera and 28% to 33% of TNMOC at the rest of the sites.

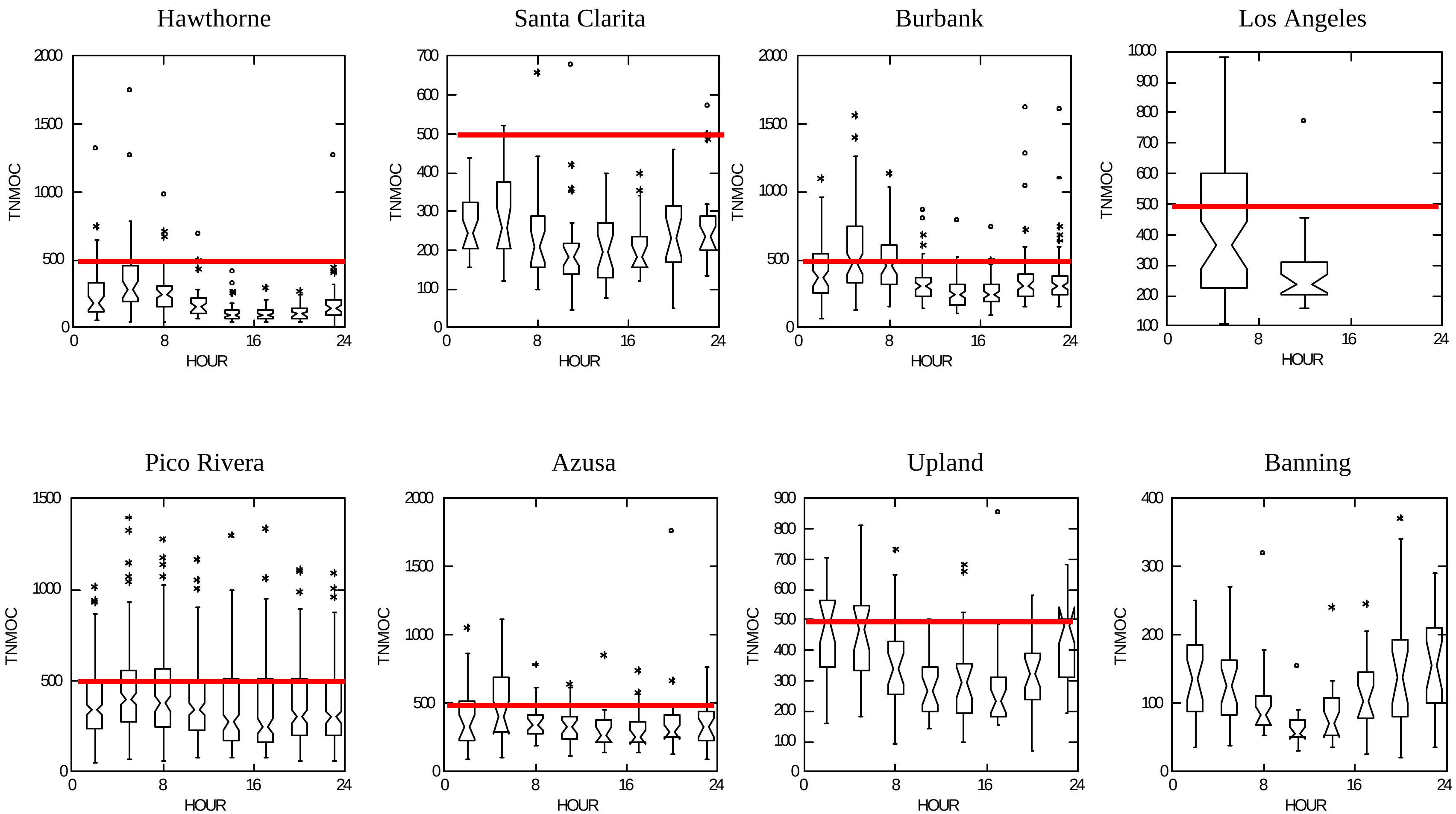

Figure 4-3. Notched box-whisker plots of total nonmethane hydrocarbon concentrations (TNMOC in ppbC) by site in 1999 and 2000. Scales vary among the sites; a horizontal line is provided at 500 ppbC on all plots except Banning for reference.

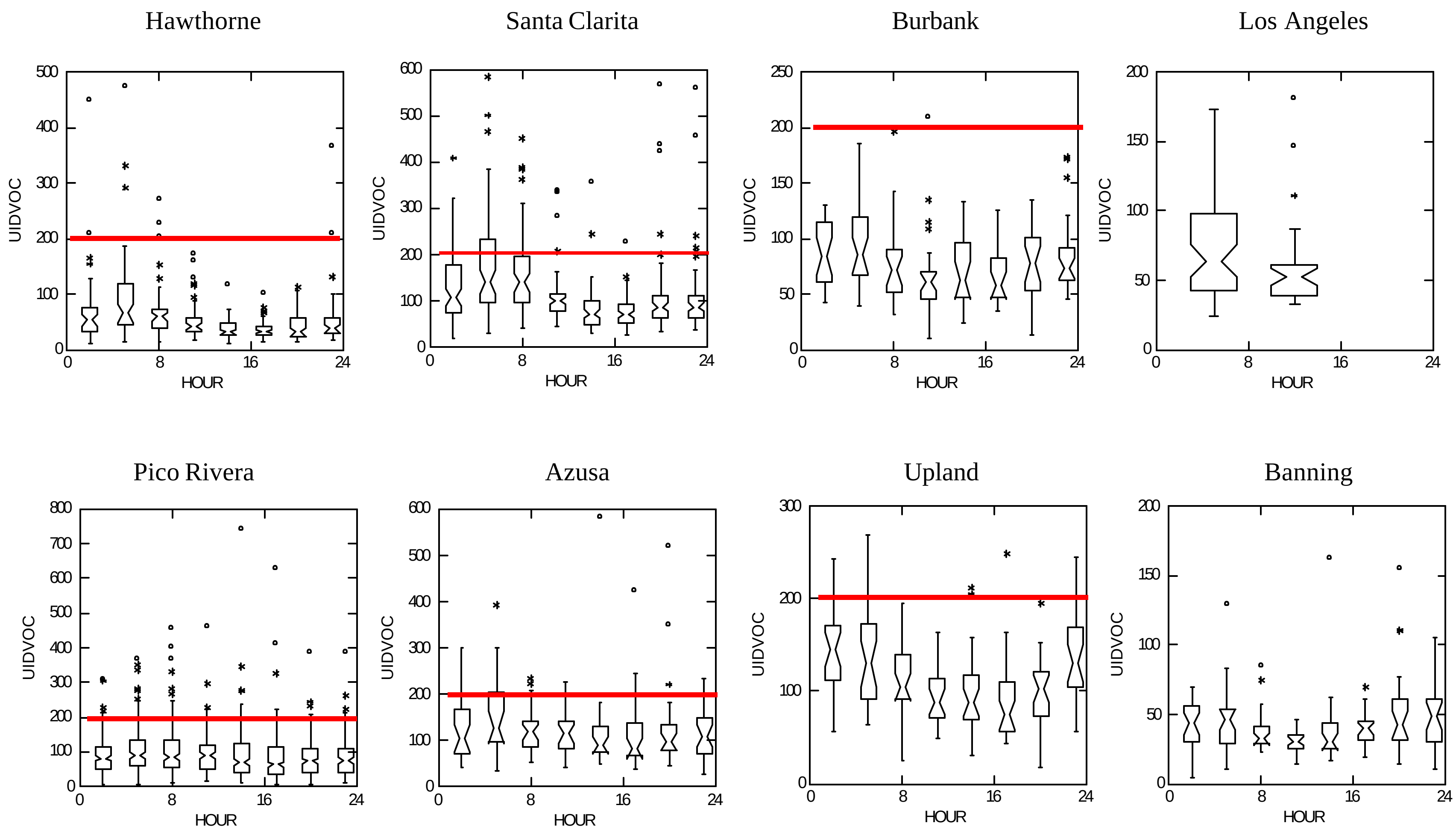

Figure 4-4. Notched box-whisker plots of unidentified mass concentrations (UIDVOC in ppbC) by site in 1999 and 2000. Scales vary among the sites; a horizontal line is provided at 200 ppbC on all plots.

Tables 4-3 and 4-4 list the ten most abundant hydrocarbons on a weight-percent basis and on a reactivity-weighted basis, respectively, at the SCAQMD PAMS and PAMS-like sites in 1999 and 2000. This analysis also helps put the most recent data in historical perspective. Observations include the following:

- Many of the same species were abundant on a concentration basis at all sites including ethane, toluene, i-pentane, propane, n-butane, n-pentane, ethene (except Santa Clarita), 2-methylpentane, and xylenes (except Banning). Methylcyclopentane and 2,3-dimethylbutane were more abundant in 1999 and 2000 than in previous years, appearing on the top ten list at Pico Rivera, Upland, and Santa Clarita.
- When reactivity is considered, the increased importance of olefins and aromatic hydrocarbons is illustrated. Ethene, xylenes, propene, toluene, i-pentane, methylcyclopentane, and 1,2,4-trimethylbenzene were in the top ten at every site, consistent with previous years.

Table 4-3. Ten most abundant hydrocarbons on a weight percent basis at the SCAQMD PAMS and PAMS-like sites 1999 and 2000. Major sources of these hydrocarbons are provided in Table 4-1.

VOC	Hawthorne	Burbank	Los Angeles	Pico Rivera	Azusa	Upland	Banning	Santa Clarita
Site Type[a]	1	1/2	Urban	2	3	4/1	2	Suburban
Ethane	✔	✔	✔	✔	✔	✔	✔	✔
Toluene	✔	✔	✔	✔	✔	✔	✔	✔
i-Pentane	✔	✔	✔	✔	✔	✔	✔	✔
Propane	✔	✔	✔	✔	✔	✔	✔	✔
n-Butane	✔	✔	✔	✔	✔	✔	✔	✔
n-Pentane	✔	✔	✔	✔	✔	✔	✔	✔
Ethylene	✔	✔	✔		✔		✔	
Xylenes	✔	✔	✔	✔	✔	✔		✔
Acetylene		✔	✔		✔		✔	
2-methylpentane	✔	✔	✔	✔	✔	✔	✔	✔
Other[b]	isbta			23dmb mcypna		23dmb mcypna	224tmp	23dmb mcypna

[a] 1 = upwind and background site; 2 = maximum ozone precursor emissions impact; 3 = maximum ozone concentration; 4 = extreme downwind site

[b] isbta = i-butane; 224tmp = 2,2,4-trimethylpentane; 23dmb = 2,3-dimethylbutane; mcypna = methylcyclopentane

Table 4-4. Ten most abundant hydrocarbons on a reactivity-weighted basis at the SCAQMD PAMS and PAMS-like sites in 1999 and 2000. Major sources of these hydrocarbons are provided in Table 4-1.

VOC	Hawthorne	Burbank	Los Angeles	Pico Rivera	Azusa	Upland	Banning	Santa Clarita
Site Type[a]	1	1/2	Urban	2	3	4/1	2	Suburban
Ethene	✔	✔	✔	✔	✔	✔	✔	✔
Toluene	✔	✔	✔	✔	✔	✔	✔	✔
Propene	✔	✔	✔	✔	✔	✔	✔	✔
1,2,4-trimethylbenzene	✔	✔	✔	✔	✔	✔	✔	✔
i-Pentane	✔	✔	✔	✔	✔	✔	✔	✔
o-Xylene	✔	✔	✔	✔	✔	✔	✔	✔
Methylcyclopentane	✔	✔	✔	✔	✔		✔	✔
1,3,5-trimethylbenzene		✔			✔			
m-Ethyltoluene		✔	✔		✔			
Other[b]	2mpna nbuta 1pnte	123tmb 2mpna	ibute 13buta	1pnte 23dmb nbuta	2mpna	23dmb 1pnte nbuta	2mpna nbuta propa	23dmb 1pnte nbuta

[a] 1 = upwind and background site; 2 = maximum ozone precursor emissions impact; 3 = maximum ozone concentration; 4 = extreme downwind site

[b] 123tmb = 1,2,3-trimethylbenzene; nbuta = n-butane; 1pnte = 1-pentene; ibute = i-butene; 2mpna = 2-methylpentane; 13buta = 1,3-butadiene; 23dmb = 2,3-dimethylbutane; propa = propane

Overall observations of spatial and temporal variation in the individual hydrocarbon concentrations and composition (weight percent) data were similar to previous work (e.g., Main et al., 1999a). To summarize a few of the important findings from this and previous work:

- At most sites, the concentrations of most species were highest during the 0500 PST sampling period (see plots in Appendix K). This is consistent with emission activities (morning "rush hour") and mixing height.
- At most of the sites, the composition changed relatively little with time of day except for a decrease in the more reactive species relative to the less reactive species (e.g., xylenes relative to benzene in Figure 4-5), increases in isoprene, and increases in evaporative emissions tracers i-butane and n-butane in the midday (e.g., **Figure 4-6**).

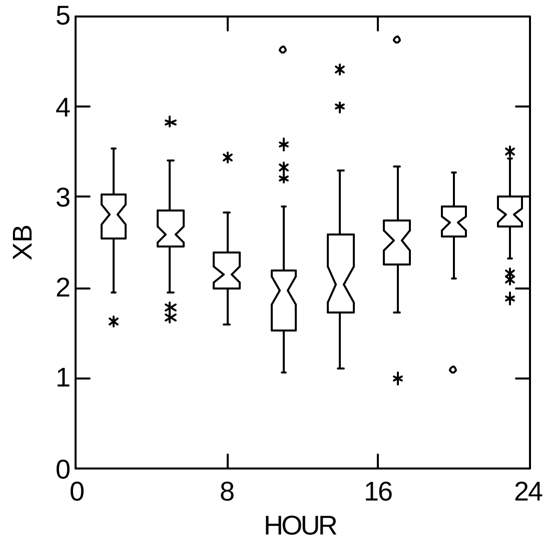

Figure 4-5. Notched box-whisker plot of xylenes-to-benzene ratios (XB) by time of day (PST) at Azusa during 1999 and 2000. Some outliers were excluded to provide better clarity of the general trend.

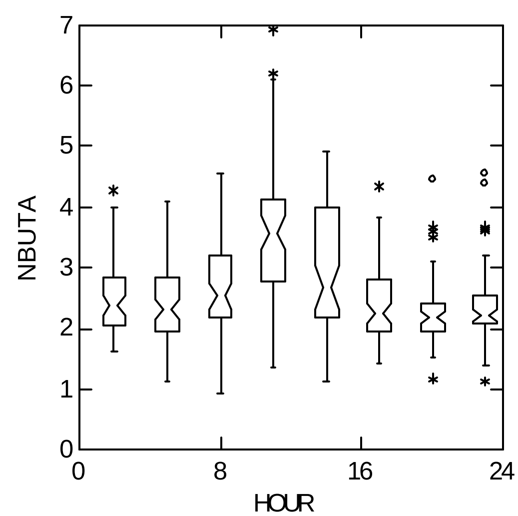

Figure 4-6. Notched box-whisker plot of n-butane (NBUTA) weight percent by time of day (PST) at Burbank during 1999 (2000 TNMOC data were not available).

4.3.3 Day-of-Week Trends in Historical PAMS Data

Have historical PAMS data indicated a pattern by day of week? What are day-of-week trends in speciation (concentration, weight percent, and reactivity-weighting) at PAMS sites? Are these trends statistically significant?

To investigate how the 1999 and 2000 PAMS data varied by day of week, we prepared

- Box-whisker plots of key species concentrations by day of week overall and by day of week for each sampling period during the day. Key species included benzene, i-butene, propane, i-pentane, toluene, xylenes, TNMOC, and the unidentified mass. We also plotted styrene and 1-pentene because of the presence of outliers.
- Fingerprints of median concentration, weight percent and reactivity-weighted composition by day of week, time of day, and by both day of week and time of day.
- A comparison of the 1999 and 2000 data plots to 1997 data analyses in Main et al., 1999a.
- Note that in this comparison, the data were collected and analyzed by the same sampling and analytical methods that add to our level of confidence in the results. Observations from the box-whisker plots and fingerprints are as follows:
- At Azusa, the median concentrations of several species appeared to increase from one day to the next between Monday through Thursday or Friday (e.g., **Figures 4-7 and 4-8**). For propane, concentrations were significantly lower on the weekends (e.g., note Sunday compared to Monday). Several high styrene concentrations occurred on the weekends.
- At Azusa, the median concentrations of most species over all time periods were highest on Wednesdays, Thursdays, and Fridays; median concentrations were lowest on Sundays (**Figure 4-9**). At 0200 PST, several species exhibited lower median concentrations on Mondays and Sundays (e.g., propane, n-decane in **Figure 4-10**). At 0500 and 0800 PST, most species had their highest median concentrations on Wednesdays and Thursdays and lowest on Mondays, Saturdays, and Sundays (e.g., **Figure 4-11**).
- At Banning, little difference was noted in concentration by day of week except that some species' concentrations were lower on Sundays than on other days (see Appendix K).
- At Burbank, concentrations for some species were lower on weekends than on weekdays (e.g., m-xylene in **Figure 4-12**) while most showed little change with day of week. Overall, the composition changes little from day to day (**Figure 4-13**) except for ethane, propane, and the butanes. However, when reactivity is considered (**Figure 4-14**), the differences in composition among the days are even less noticeable. These observations remain consistent for each sampling period as well (Appendix K). Results for Los Angeles were similar to Burbank.

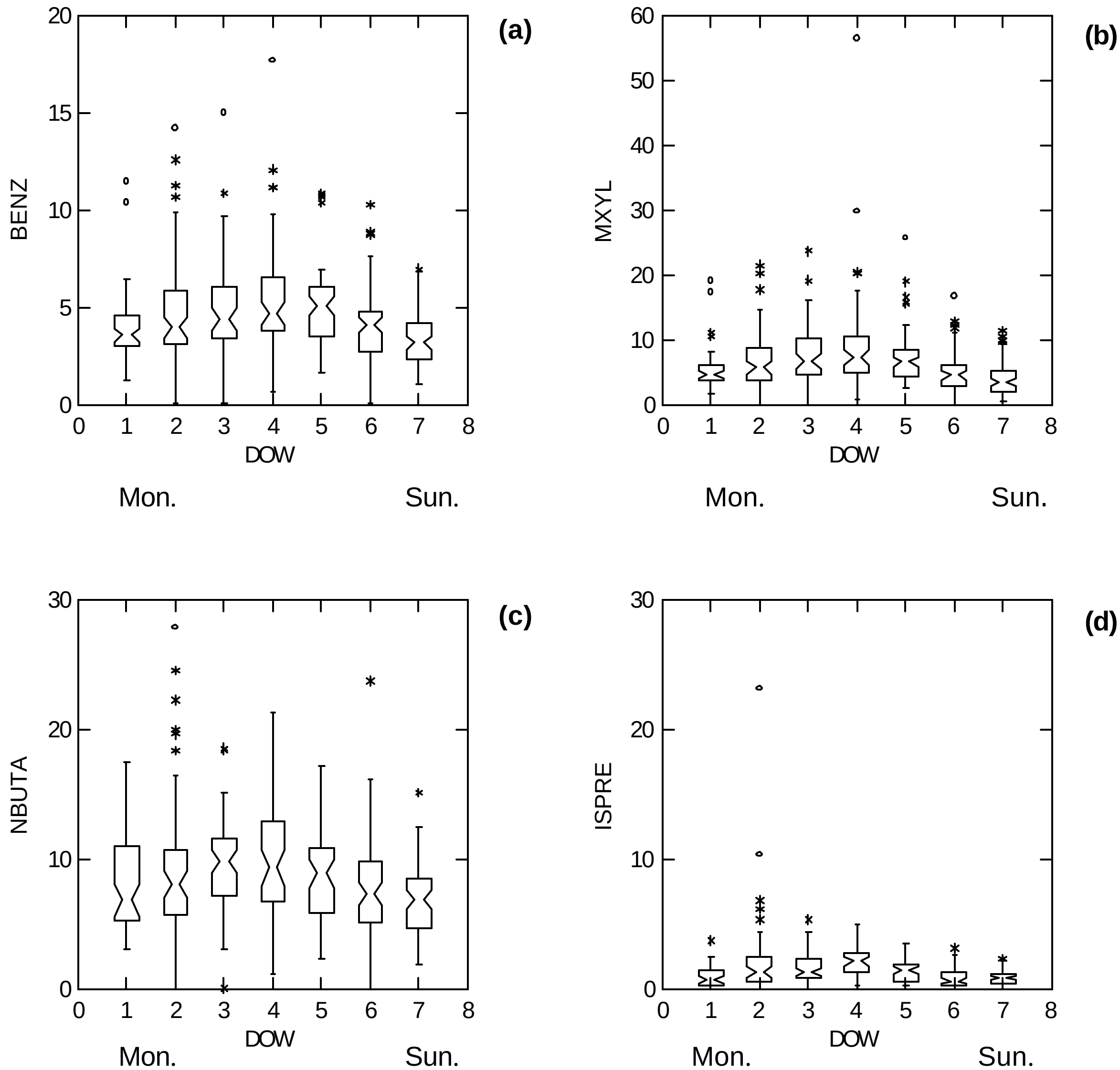

Figure 4-7. Notched box-whisker plots of (a) benzene (BENZ), (b) m-xylene (MXYL), (c) n-butane (NBUTA), and (d) isoprene (ISPRE) concentrations (ppbC) by day of week (DOW) at Azusa in 1999 and 2000. All time periods are included.

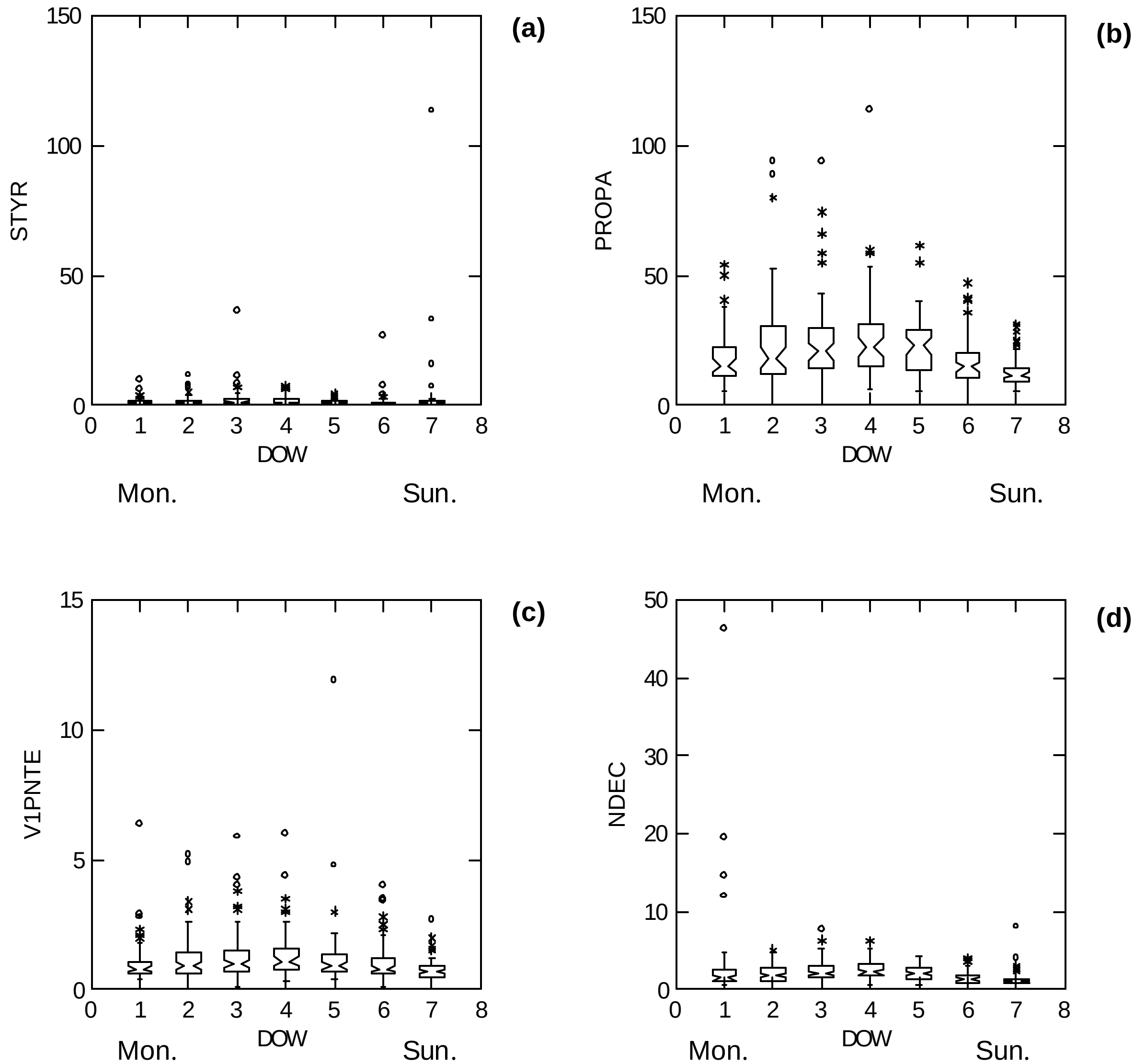

Figure 4-8. Notched box-whisker plots of (a) styrene (STYR), (b) propane (PROPA), (c) 1-pentene (V1PNTE), and (d) n-decane (NDEC) concentrations (ppbC) by day of week (DOW) at Azusa in 1999 and 2000. All time periods are included.

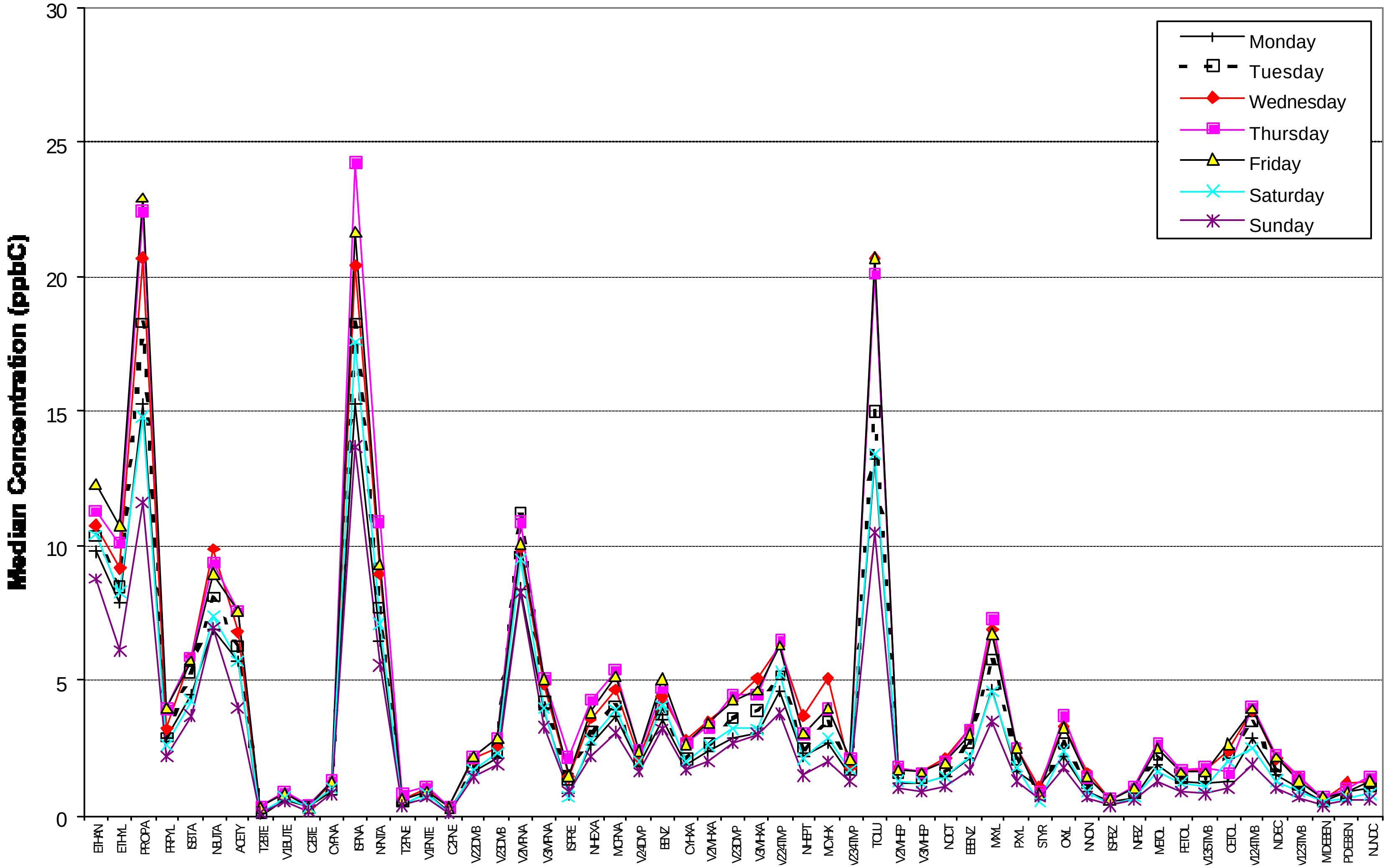

Figure 4-9. Median concentrations (ppbC) of hydrocarbons at Azusa (1999 and 2000 data combined) by day of week (all sampling periods combined). Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

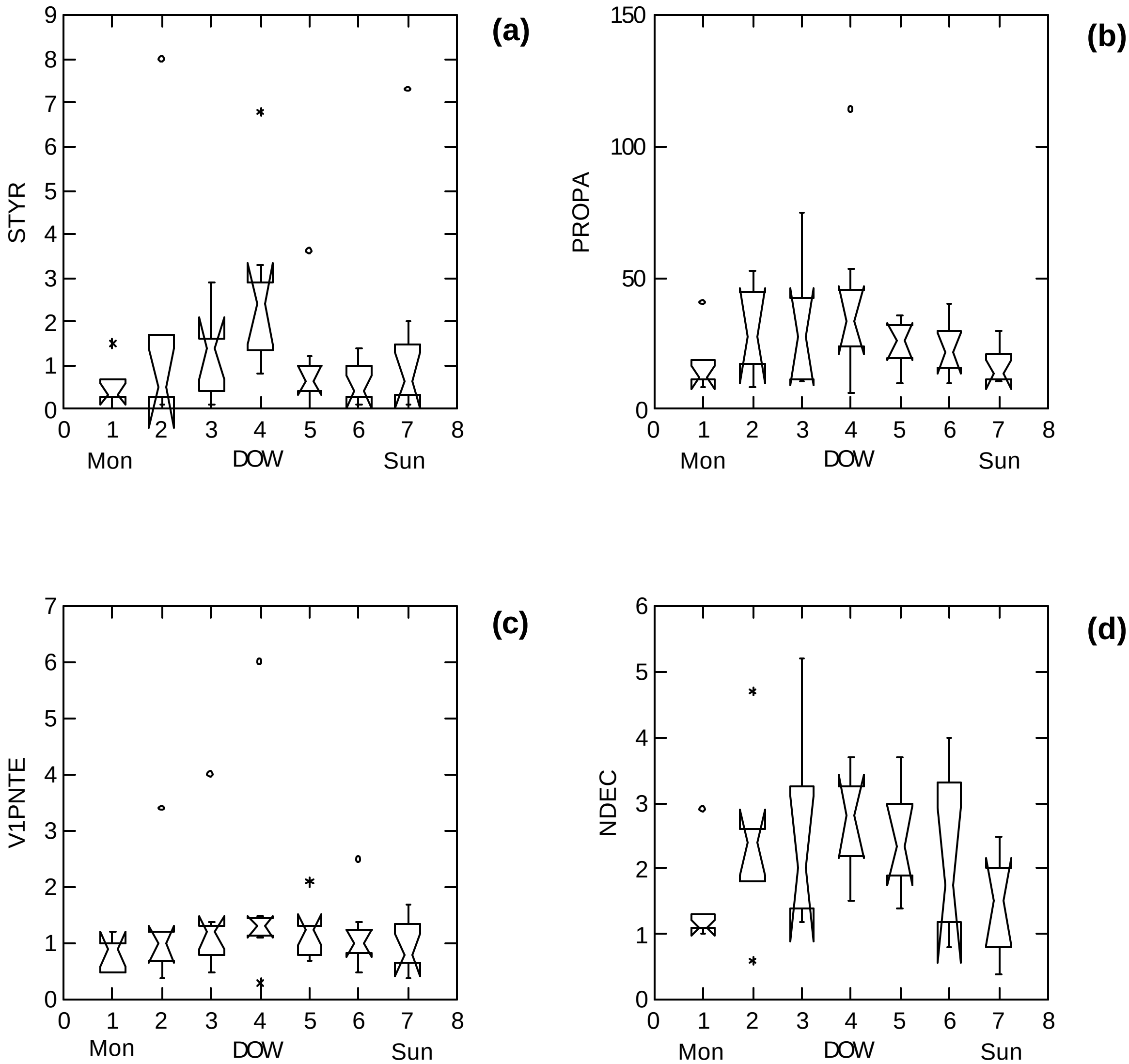

Figure 4-10. Notched box-whisker plots of (a) styrene (STYR), (b) propane (PROPA), (c) 1-pentene (V1PNTE), and (d) n-decane (NDEC) concentrations (ppbC) by day of week at Azusa in 1999 and 2000 at 0200 PST.

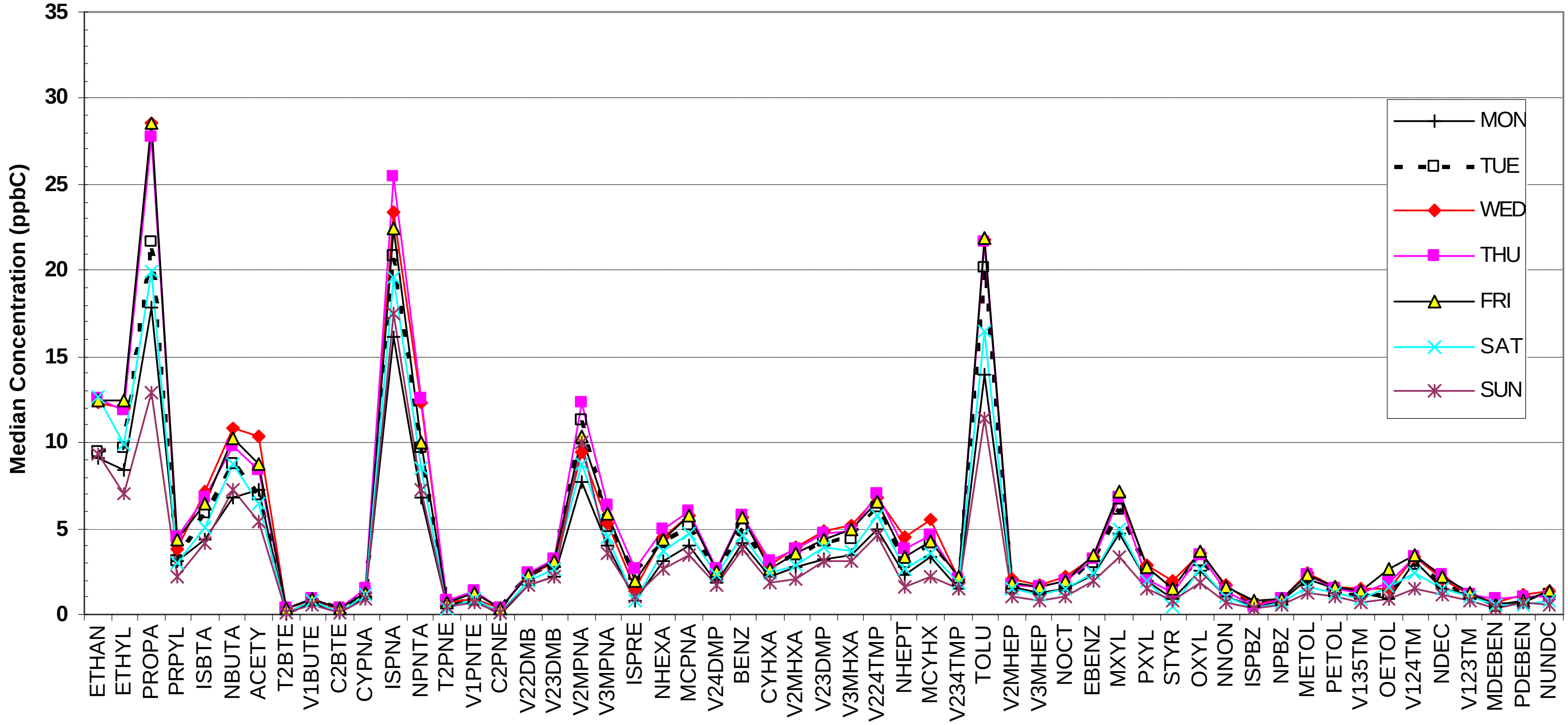

Figure 4-11. Median concentrations (ppbC) of hydrocarbons at Azusa (1999 and 2000 data combined) by day of week at 0800 PST. Species abbreviations are provided in Appendix J. The "V" in front of the abbreviation signifies "variable" and is added by the SYSTAT software.

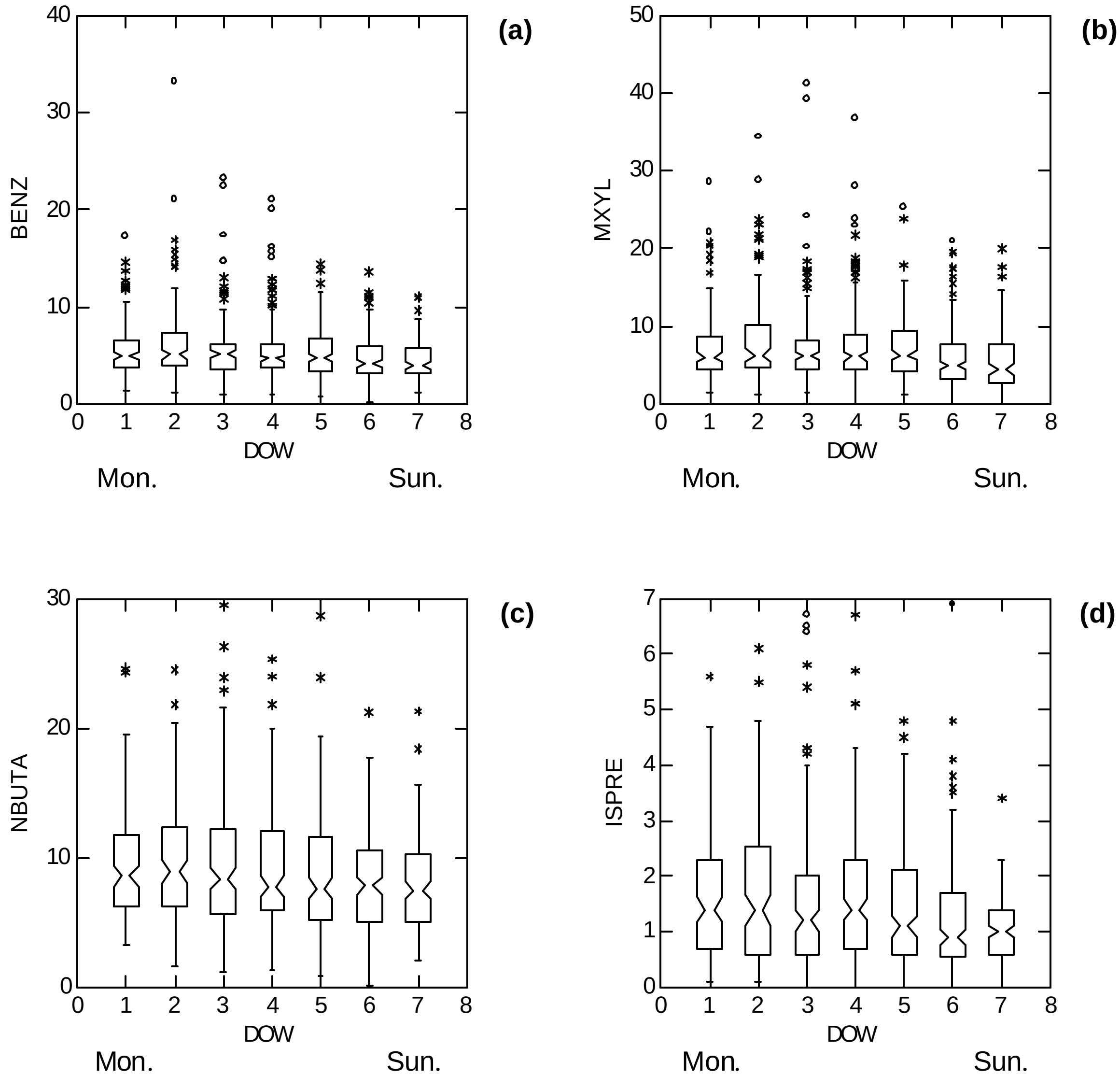

Figure 4-12. Notched box-whisker plots of (a) benzene (BENZ), (b) m-xylene (MXYL), (c) n-butane (NBUTA), and (d) isoprene (ISPRE) concentrations (ppbC) by day of week (DOW) at Burbank in 1999 and 2000. All time periods are included.

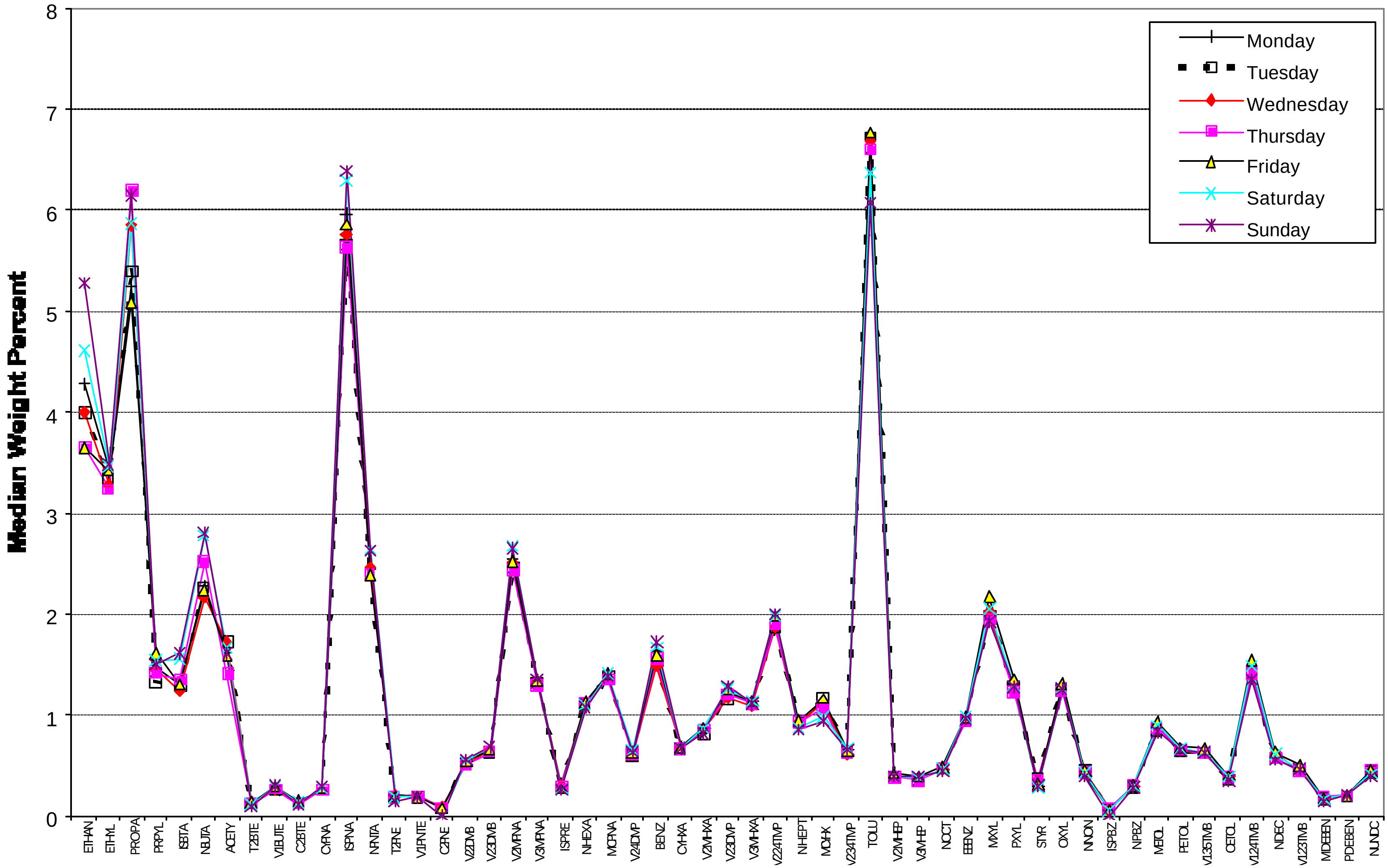

Figure 4-13. Median weight percent of hydrocarbons at Burbank (1999 only) by day of week (all sampling periods combined). Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

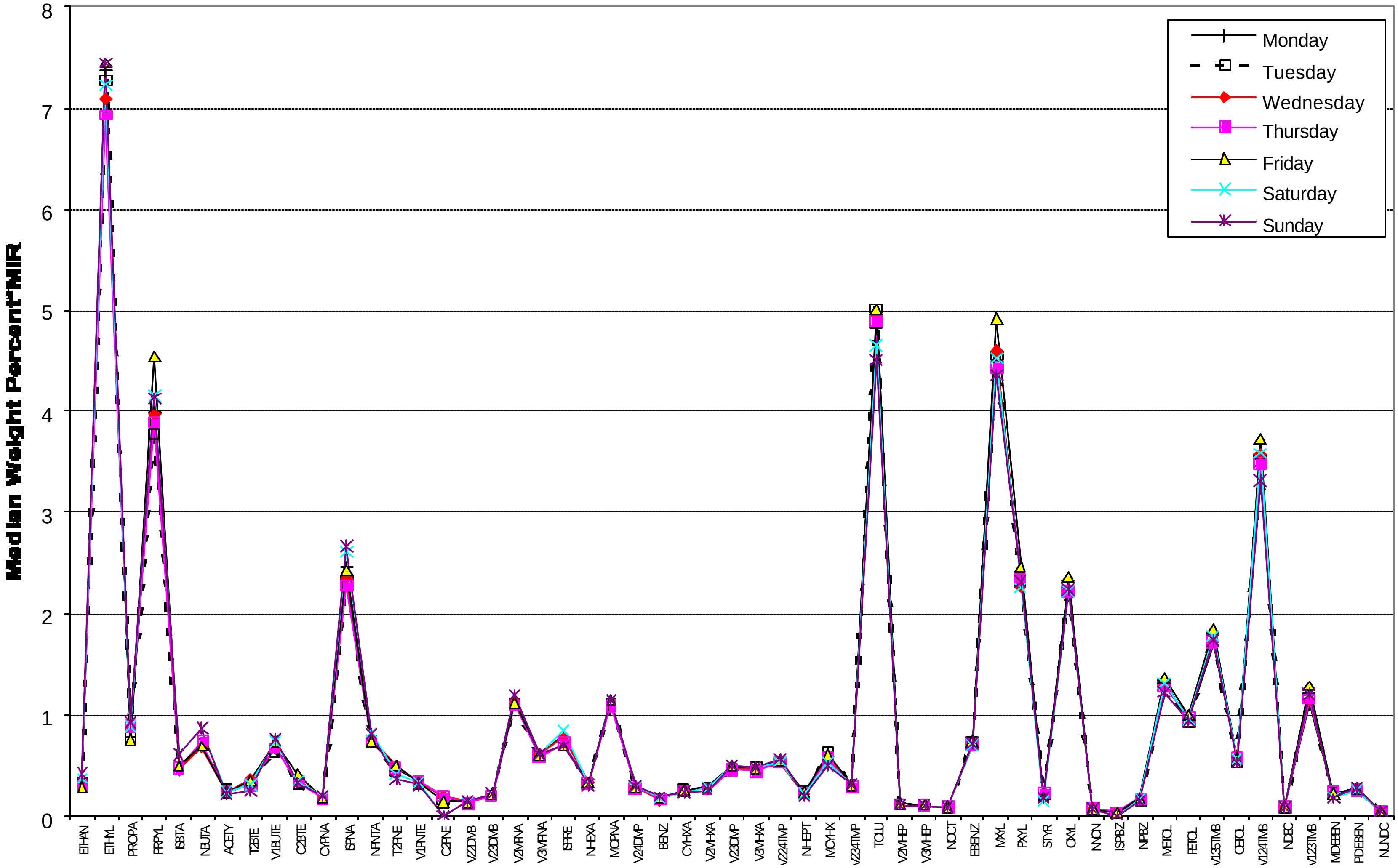

Figure 4-14. Median reactivity-weighted weight percent of hydrocarbons at Burbank (1999 only) by day of week (all sampling periods combined). Species abbreviations are provided in Appendix J. The "V" in front of the abbreviation signifies "variable" and is added by the SYSTAT software.

- At Hawthorne, concentrations were generally higher on Wednesdays (e.g., propane in Figure 4-15). Note that there were more styrene and 1-pentene high concentration outliers on weekdays than on weekends. In general, the composition varied from day to day more at this site than at other sites. The composition (weight percent) by day of week showed higher styrene fractions on Fridays, higher m-xylene fractions on Mondays, higher ethane, propane, and butane fractions on Sundays, and higher toluene fractions on Wednesdays (Figure 4-16).
- At Pico Rivera, concentrations for some species (e.g., styrene and propane in Figure 4-17) were lower on weekends than on weekdays while others showed little difference among the days (e.g., benzene in Figure 4-18). When the data are investigated by time of day and day of week, several species exhibit lower concentrations on Sundays in the early morning (e.g., Figure 4-19).
- At Santa Clarita, the concentrations of some species varied by day of week, but no discernible pattern was observed.
- At Upland, some species, including decane, had lower concentrations on Sunday than on other days (e.g., Figure 4-20). However, most of the hydrocarbons showed little day-to-day variation.

These investigations reveal day-of-week patterns in the data for some hydrocarbons; however, differences are typically small and not necessarily consistent from site to site. An overall observation is that concentrations tend to be lower on Sundays than other days. This observation can be supported statistically (e.g., no overlap between the confidence intervals around the medians) at most sites for many of the hydrocarbons. Table 4-5 summarizes the day-of-week differences in median TNMOC concentrations during 1999 and 2000. For the sites exhibiting a day-of-week difference, Sunday TNMOC concentrations were 24% to 27% lower than weekdays. Saturday concentrations were 10% to 27% lower than weekdays.

Table 4-5. Summary of day-of-week differences in median TNMOC concentrations during 1999 and 2000.

Site	Median TNMOC (ppbC) by Day of Week							Comment
	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
Azusa	280	378	361	384	346	286	267	Saturday concentrations about 22% lower than Tuesday through Friday. Sunday TNMOC about 27% lower than Tuesday through Friday.
Banning	113	71	90	108	95	107	95	
Burbank	366	367	332	319	322	246	250	
Hawthorne	148	142	171	151	136	131	146	Weekend TNMOC concentrations about 27% lower than weekday.
Los Angeles	243	242	282	459	267	287	259	
Pico Rivera	344	417	335	351	330	300	270	Saturday concentrations 15% lower than weekdays. Sunday concentrations 24% lower than weekday.
Santa Clarita	226	182	253	291	213	210	189	Saturday concentrations 10% lower than weekdays. Sunday concentrations 27% lower than weekdays.
Upland	300	257	487	365	327	345	311	

4.3.4 Comparison of Special Studies Data at Los Angeles N. Main with Historical Data

How did the special studies data collected at Los Angeles N. Main during October 2000 compare with data collected in previous years at the same site? Did the composition or concentration data collected during the field study time period differ significantly from the historical data?

We prepared plots of the concentration, weight percent, and reactivity-weighted data collected at Los Angeles N. Main during 1999 and 2000 to compare the data collected during the field study with the median values from the historical/routine data collection. Observations from this investigation follow:

- The 0500 PST concentrations on Saturday, October 7, 2000, were lower than the historical medians while most species had higher concentrations on Saturday, September 30, 2000, compared to historical medians (Figure 4-21). The TNMOC concentrations on both of the study period days were outside the interquartile range of the historical data. However, on a weight-percent basis (Figure 4-22), the fingerprints are similar except the C2 through C4 hydrocarbons on September 30. Toluene, i-pentane, and the xylenes also exhibit large differences between the special study samples and the historical median.

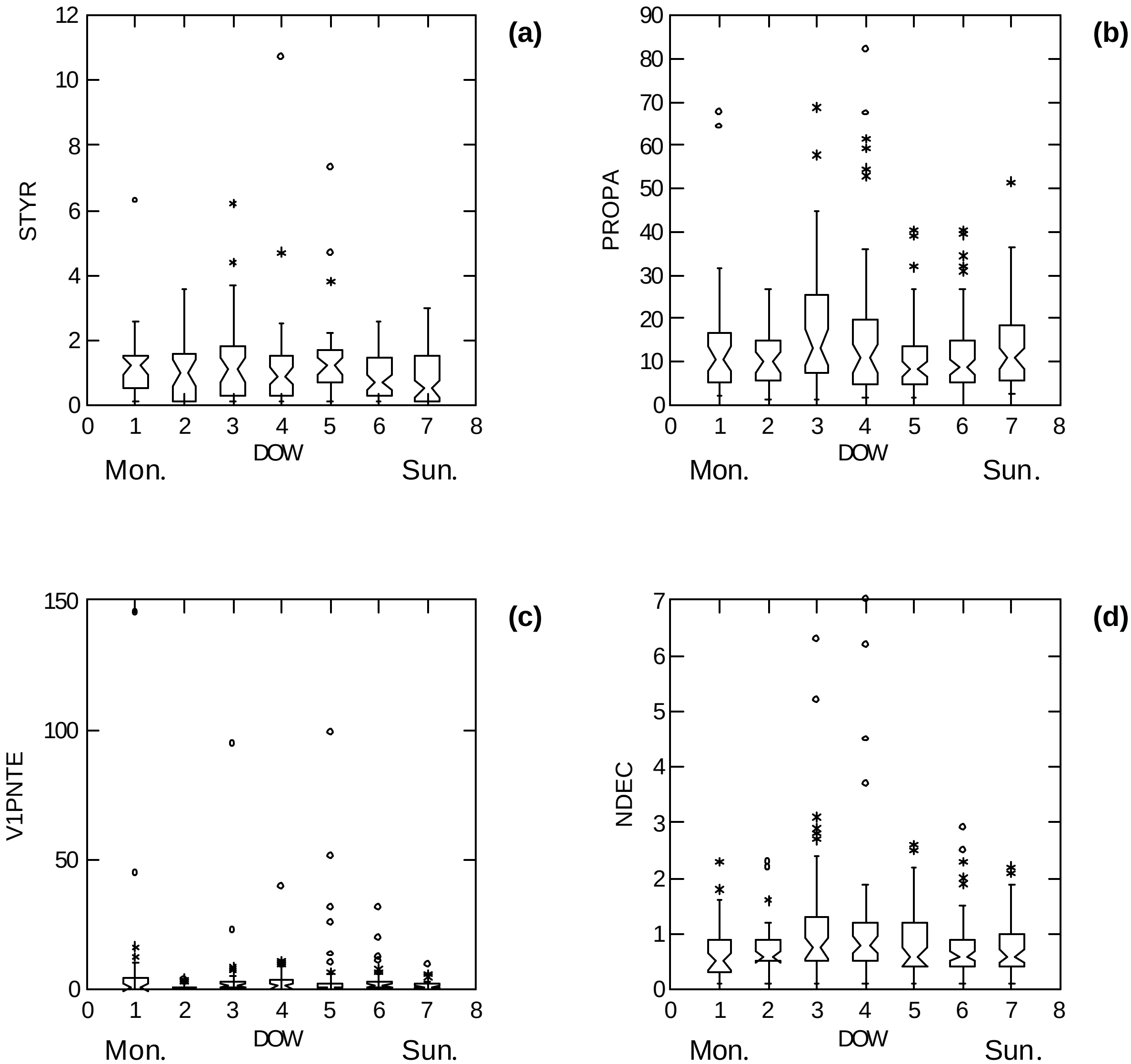

Figure 4-15. Notched box-whisker plots of (a) styrene (STYR), (b) propane (PROPA), (c) 1-pentene (V1PNTE), and (d) n-decane (NDEC) concentrations (ppbC) by day of week at Hawthorne in 1999 and 2000. All time periods are included.

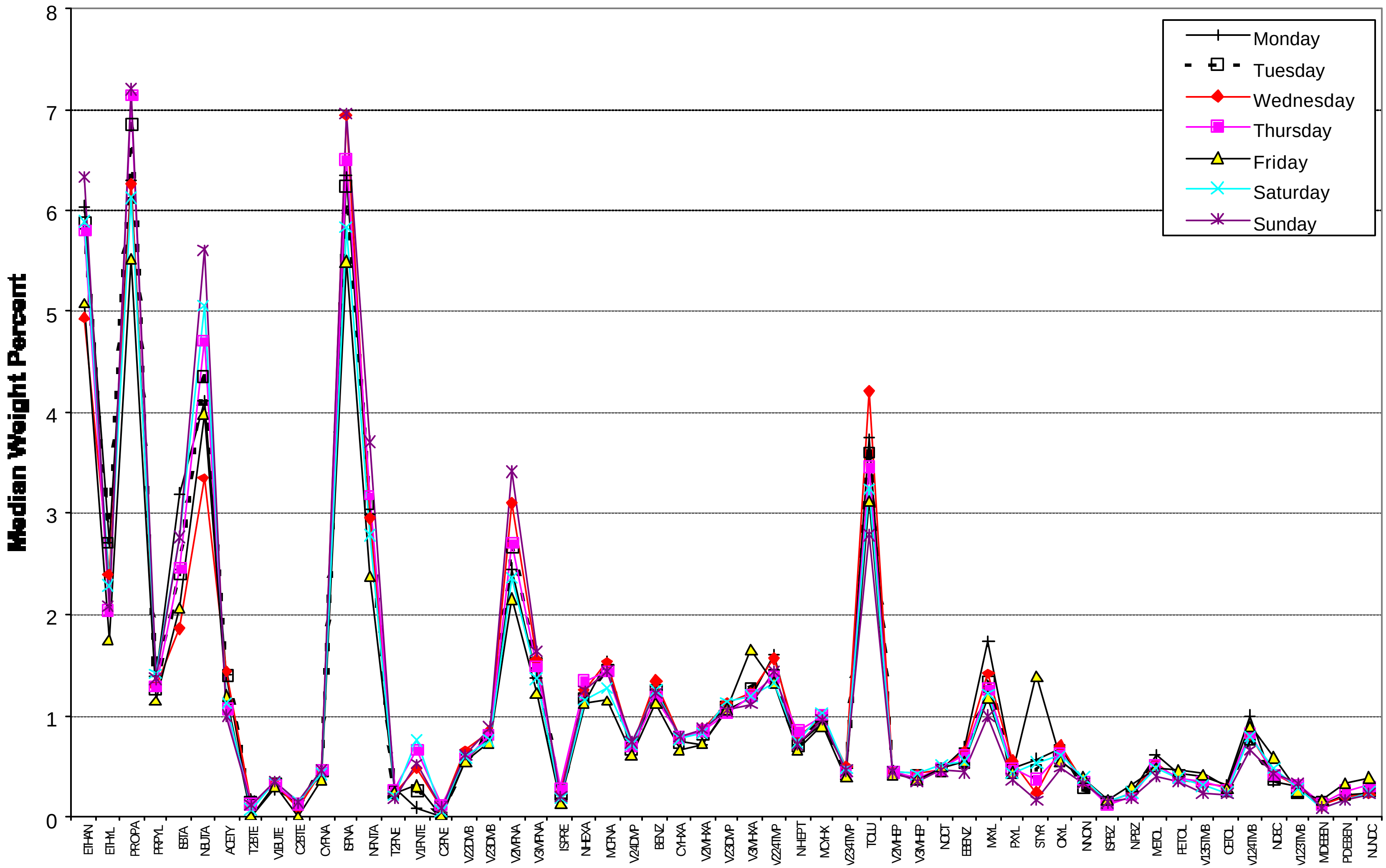

Figure 4-16. Median weight percent of hydrocarbons at Hawthorne (1999 and 2000) by day of week (all sampling periods combined). Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

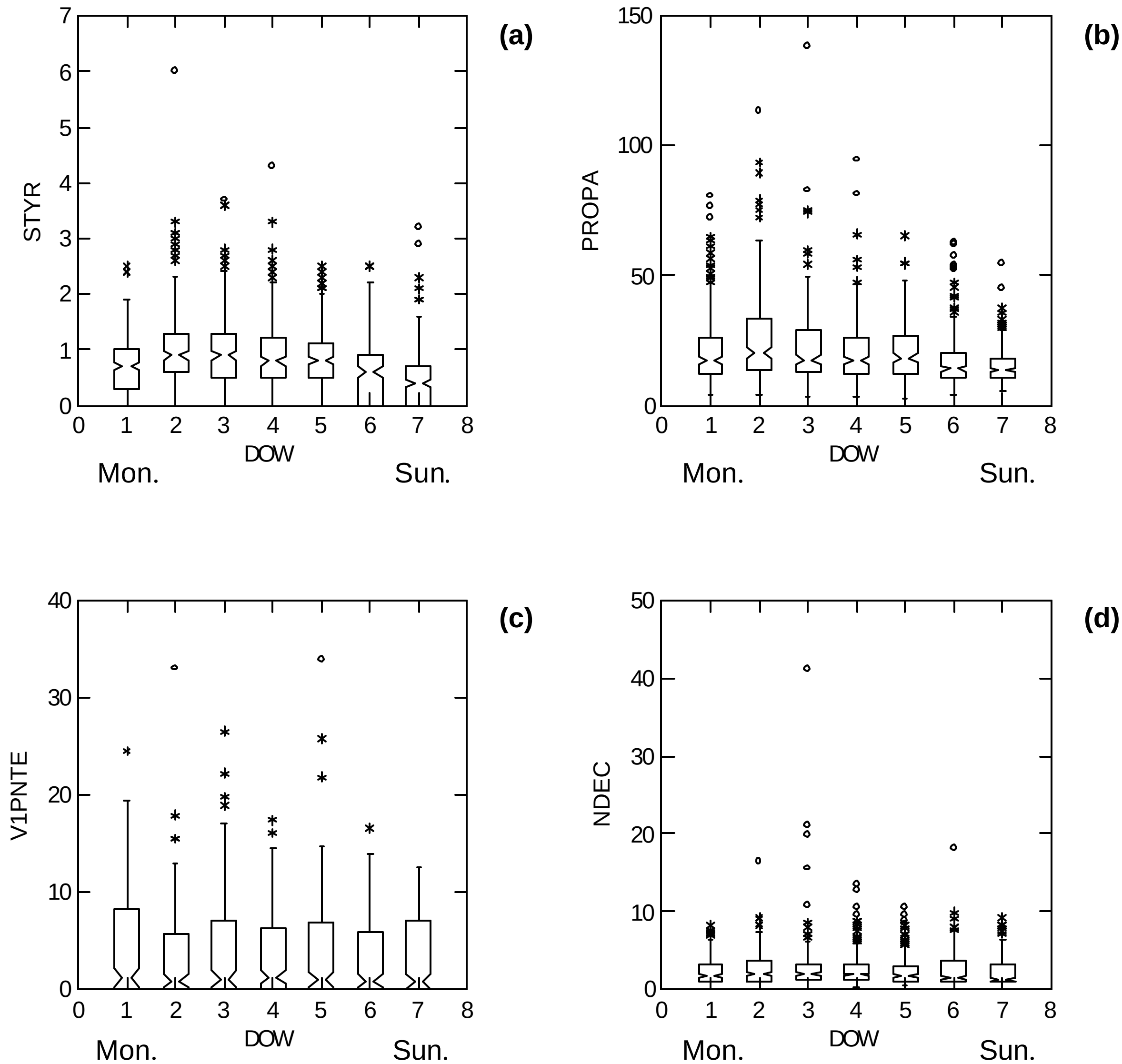

Figure 4-17. Notched box-whisker plots of (a) styrene (STYR), (b) propane (PROPA), (c) 1-pentene (V1PNTE), and (d) n-decane (NDEC) concentrations (ppbC) by day of week (DOW) at Pico Rivera in 1999 and 2000. All time periods are included.

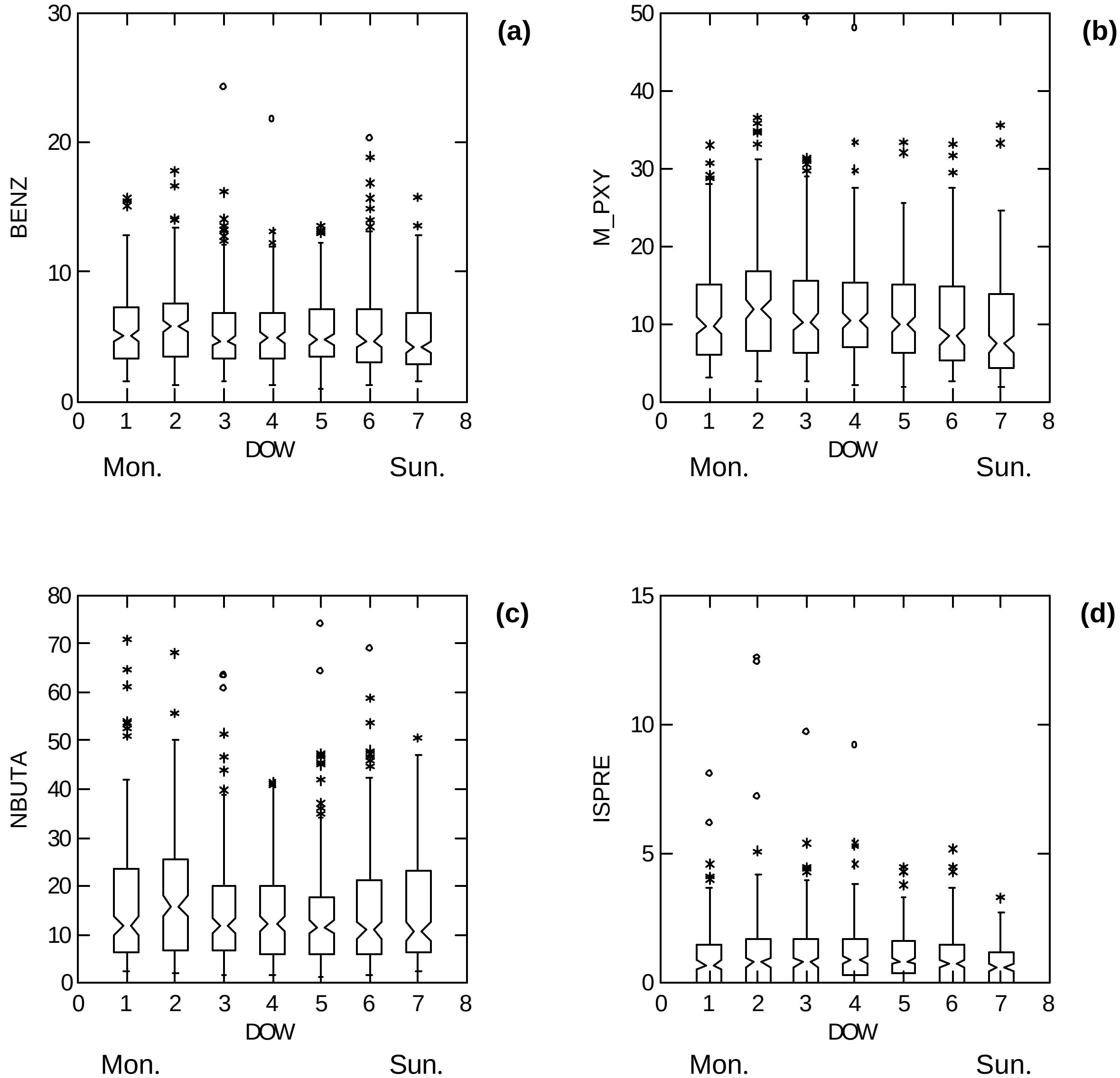

Figure 4-18. Notched box-whisker plots of (a) benzene (BENZ), (b) m- & p-xylene (M_PXY), (c) n-butane (NBUTA), and (d) isoprene (ISPRE) concentrations (ppbC) by day of week (DOW) at Pico Rivera in 1999 and 2000. All time periods are included.

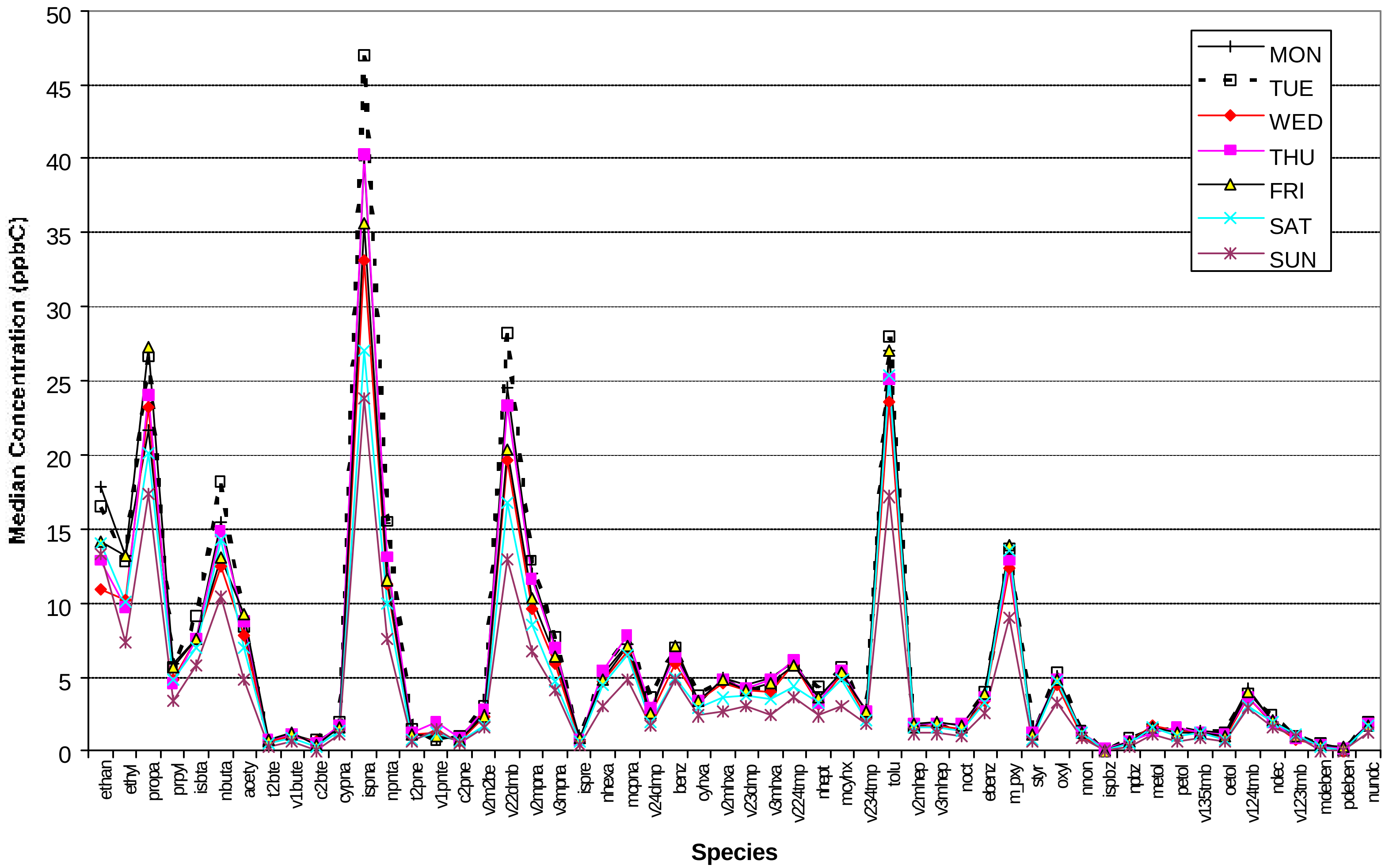

Figure 4-19. Median concentrations (ppbC) of hydrocarbons at Pico Rivera (1999 and 2000 data combined) by day of week at 0500 PST. Species abbreviations are provided in Appendix J. The "V" in front of the abbreviation signifies "variable" and is added by the SYSTAT software.

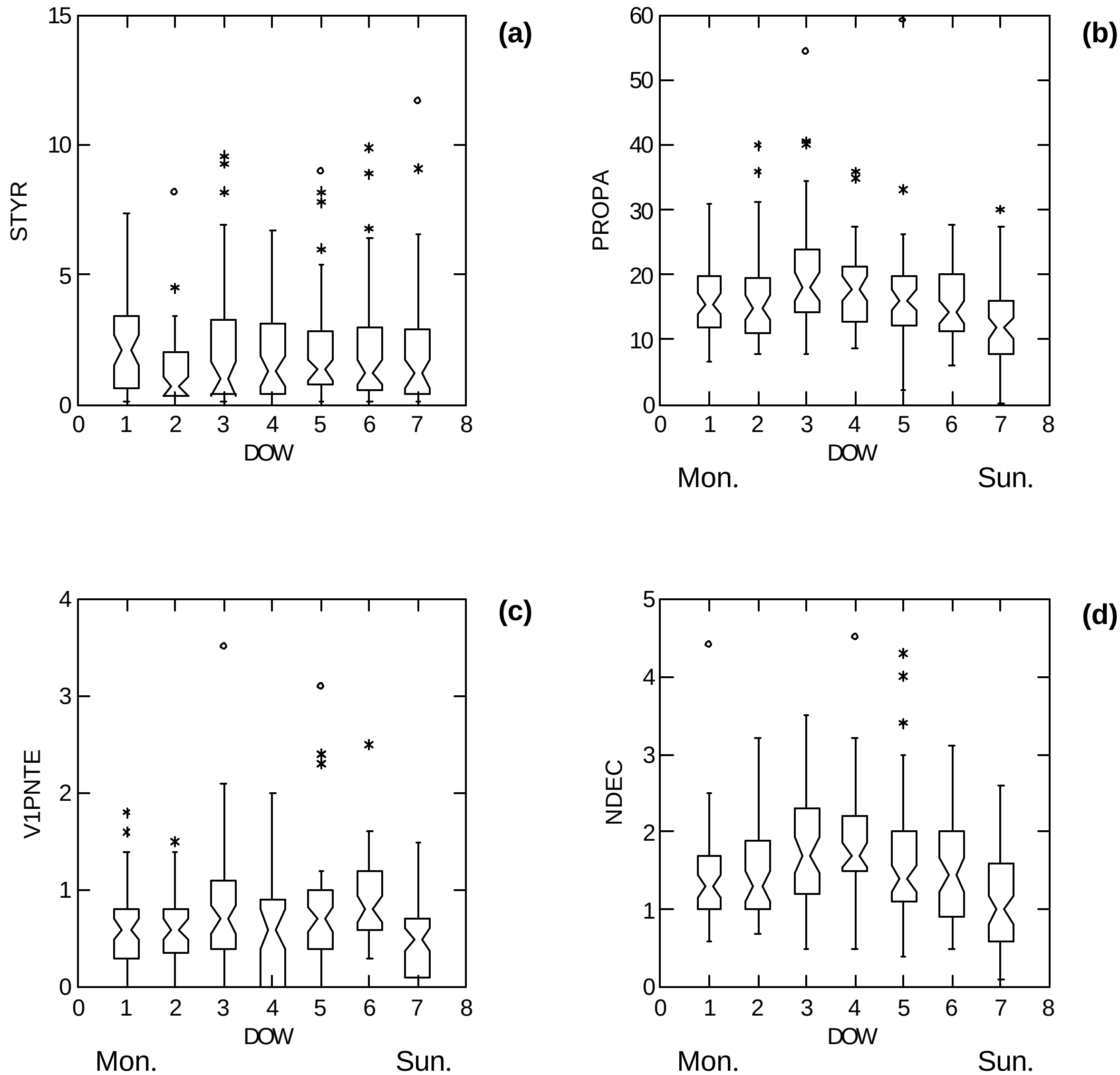

Figure 4-20. Notched box-whisker plots of (a) styrene (STYR), (b) propane (PROPA), (c) 1-pentene (V1PNTE), and (d) n-decane (NDEC) concentrations (ppbC) by day of week at Upland in 1999 and 2000. All time periods are included.

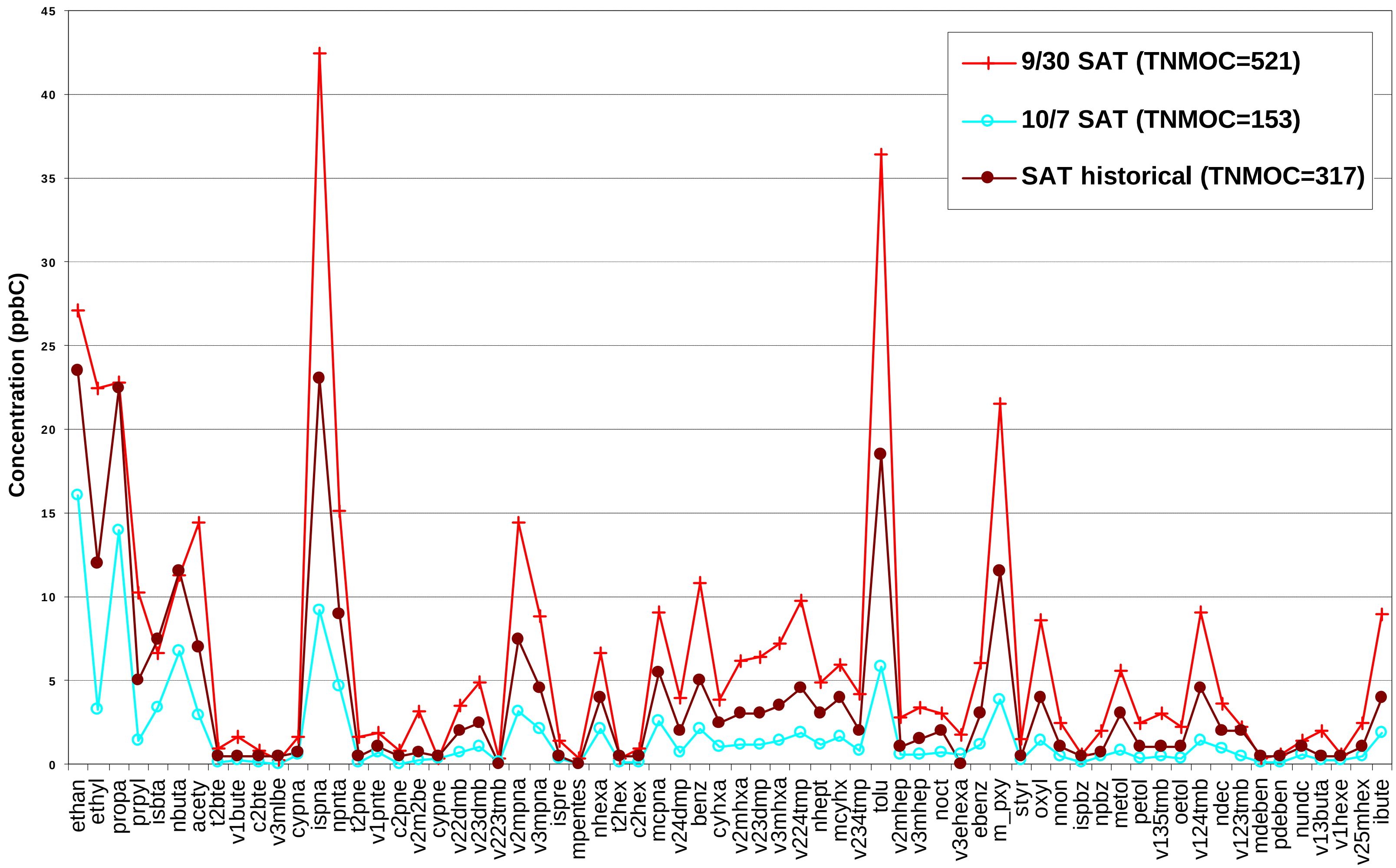

Figure 4-21. Median concentrations (ppbC) of hydrocarbons at Los Angeles N. Main at 0500 PST during the special study period compared to historical data (Saturdays). A notched box-whisker plot of historical TNMOC concentrations (ppbC) at 0500 PST is also provided. Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

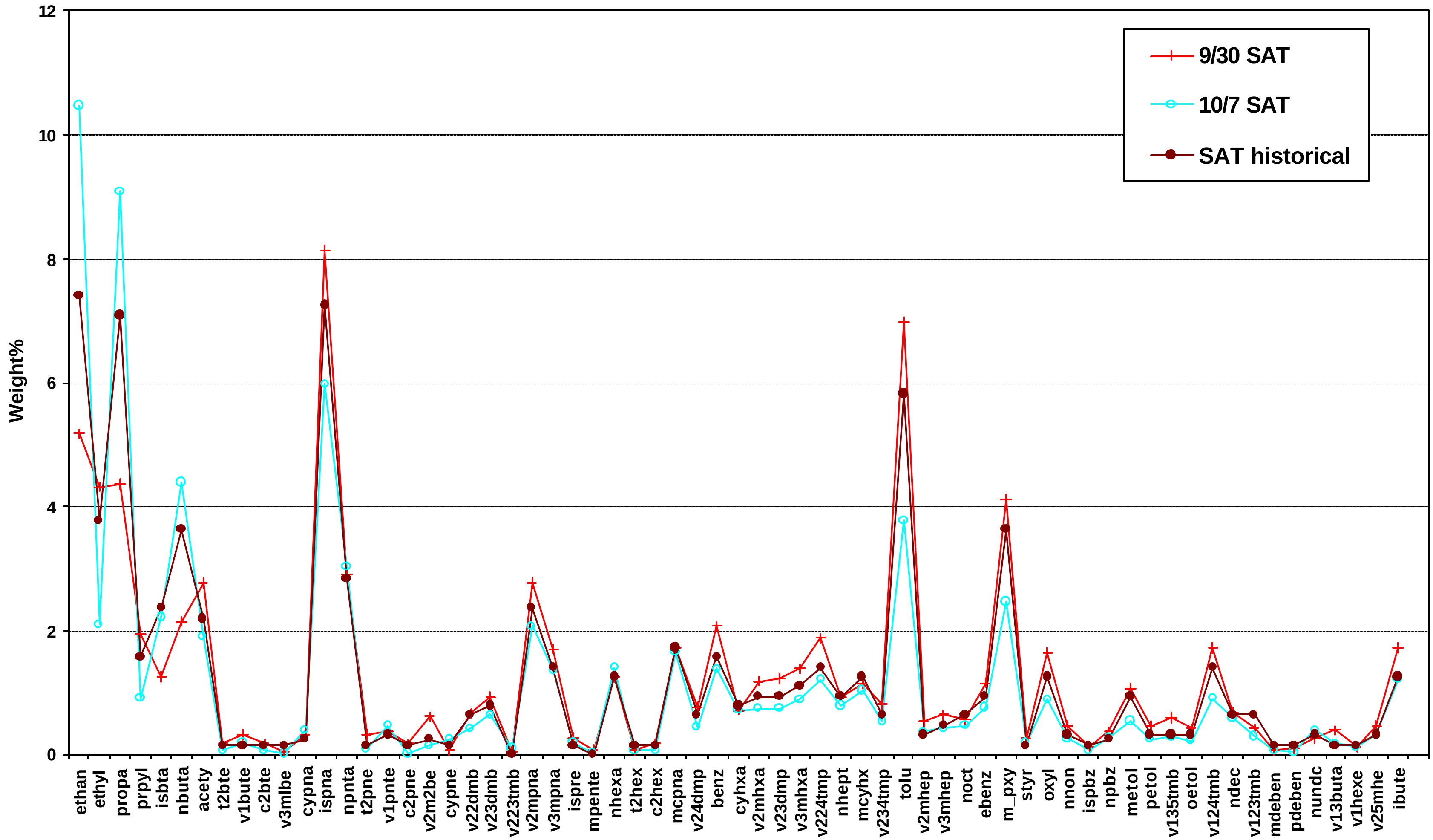

Figure 4-22. Median weight percent of hydrocarbons at Los Angeles N. Main at 0500 PST during the special study period compared to historical data (Saturdays). Species abbreviations are provided in Appendix J. The "V" in front of the abbreviation signifies "variable" and is added by the SYSTAT software.

- On the two Sundays of the study (October 1 and 8), concentrations were higher than historical medians for nearly all hydrocarbons (Figure 4-23). However, the composition (weight percent normalized over the sum of the PAMS species for this example, Figure 4-24) was remarkably similar to that from historical data.
- The Monday, October 2, concentrations at 0500 PST were lower than historical medians except for o-ethyltoluene, n-decane, and 1,2,3-trimethylbenzene (Appendix L). The composition of the sample collected during the special study period was similar to the historical Monday data with the same exceptions. In addition, the i-pentane and toluene fractions were significantly lower in the October 2 sample than historically (Figure 4-25).
- The Wednesday, October 4, concentrations (and composition) at 0500 PST were nearly the same as historical medians except for several C2-C3 species (i.e., ethane, propane, and the butanes – Figure 4-26). This may be indicative of more carryover and accumulation of these less reactive species.

In most of the special studies samples, the composition and concentrations are similar to historical medians. In many cases, the exceptions fall within the historical interquartile range.

4.3.5 Special Study Data

How did special study canister samples collected by DRI at Dodger Stadium (near Los Angeles N. Main) compare to speciation at the PAMS site? Were there day-of-week differences in speciation during the field study?

In this comparison, the VOCs were sampled over different time periods using different collection and analysis methods. This analysis is not meant to be quantitative or comprehensive. Rather, the comparison is provided to obtain a general overview of how well the data compare. We compared the samples collected in the van by DRI near Dodger Stadium (collected between 0400 and 0700 PST) with the Los Angeles N. Main historical median (at 0500 PST) on a normalized basis (**Figure 4-27**). Concentrations were divided by the sum of the species plotted because the DRI TNMOC includes many more compounds than those reported as part of the PAMS program. We also included the median of samples collected in the van near Industry Hills and at the truck stop for reference. The composition among the samples shown in the figure is remarkably similar. The largest differences are noted for ethane and propane.

DRI data analyses focused mostly on the total hydrocarbon concentrations. One of our objectives was to compare the speciation of WD/WE sample pairs from the study. We compared the following sample pairs: (1) Wednesday, October 4, and Saturday, October 7, and (2) Monday, October 2, and Sunday, October 8. Our observations are as follows:

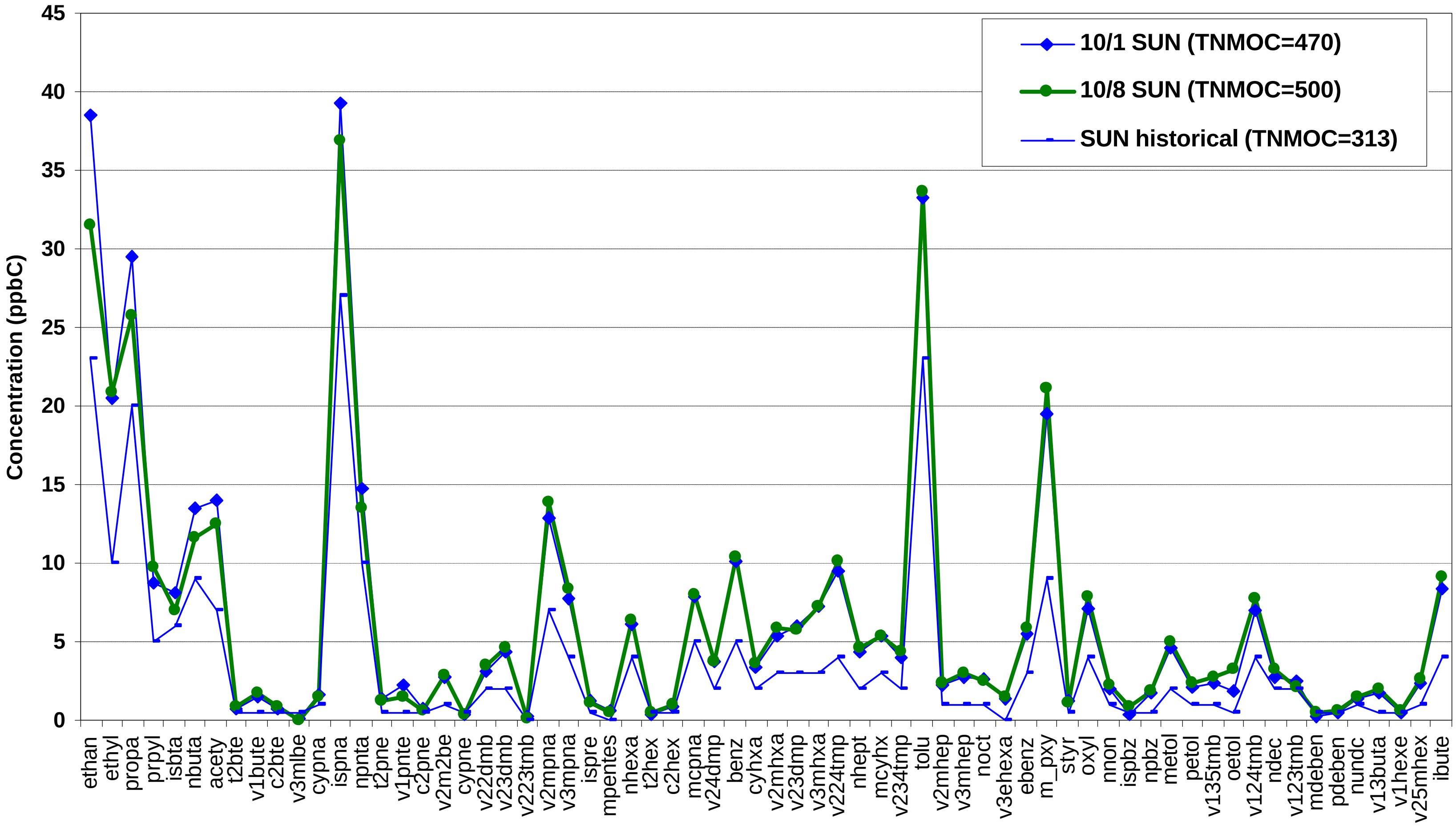

Figure 4-23. Median concentrations (ppbC) of hydrocarbons at Los Angeles N. Main at 0500 PST during the special study period compared to historical data (Sundays). A notched box-whisker plot of historical TNMOC concentrations (ppbC) at 0500 PST is also provided. Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

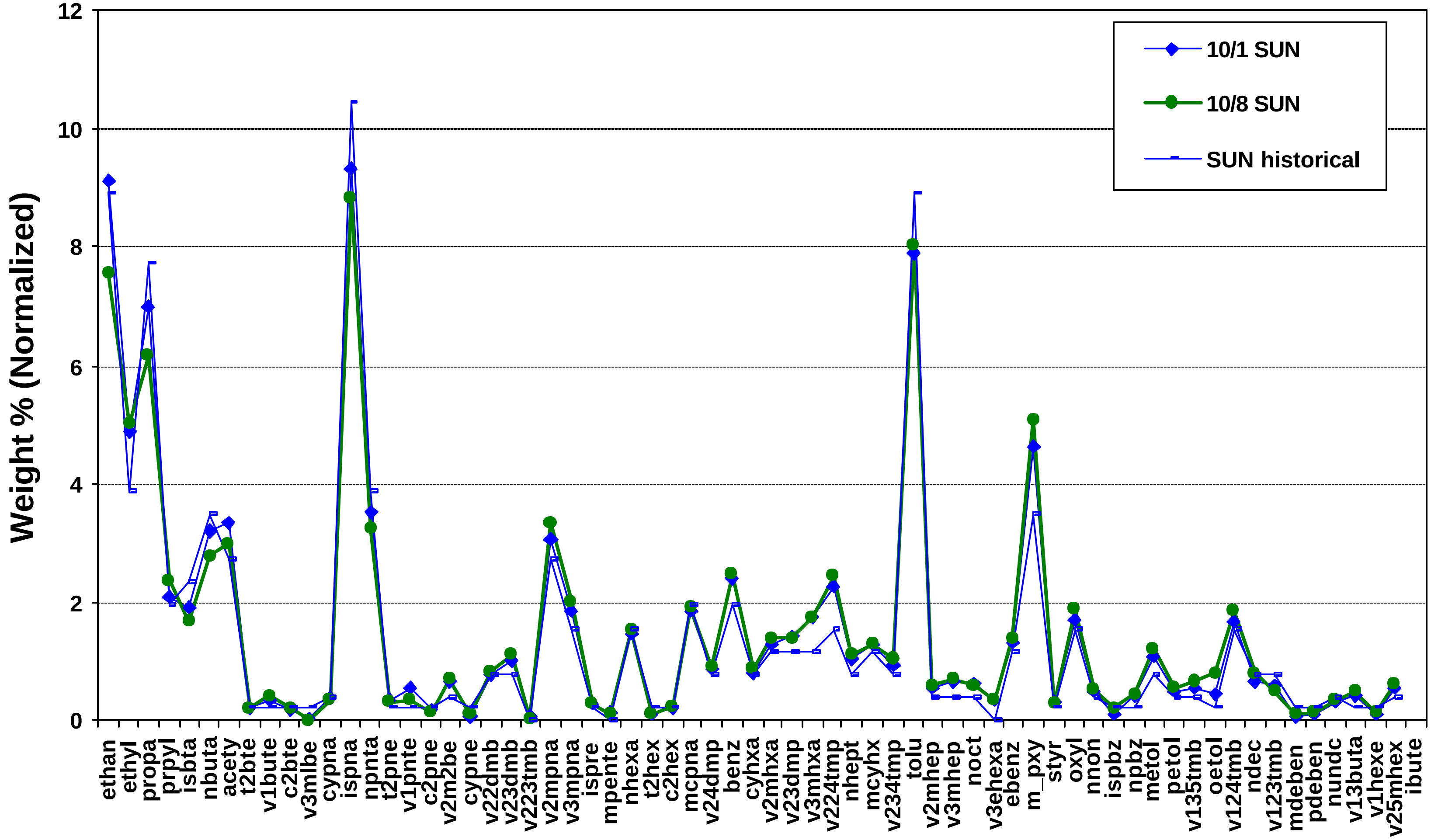

Figure 4-24. Median weight percent of hydrocarbons at Los Angeles N. Main at 0500 PST during the special study period compared to historical data (Sundays). Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

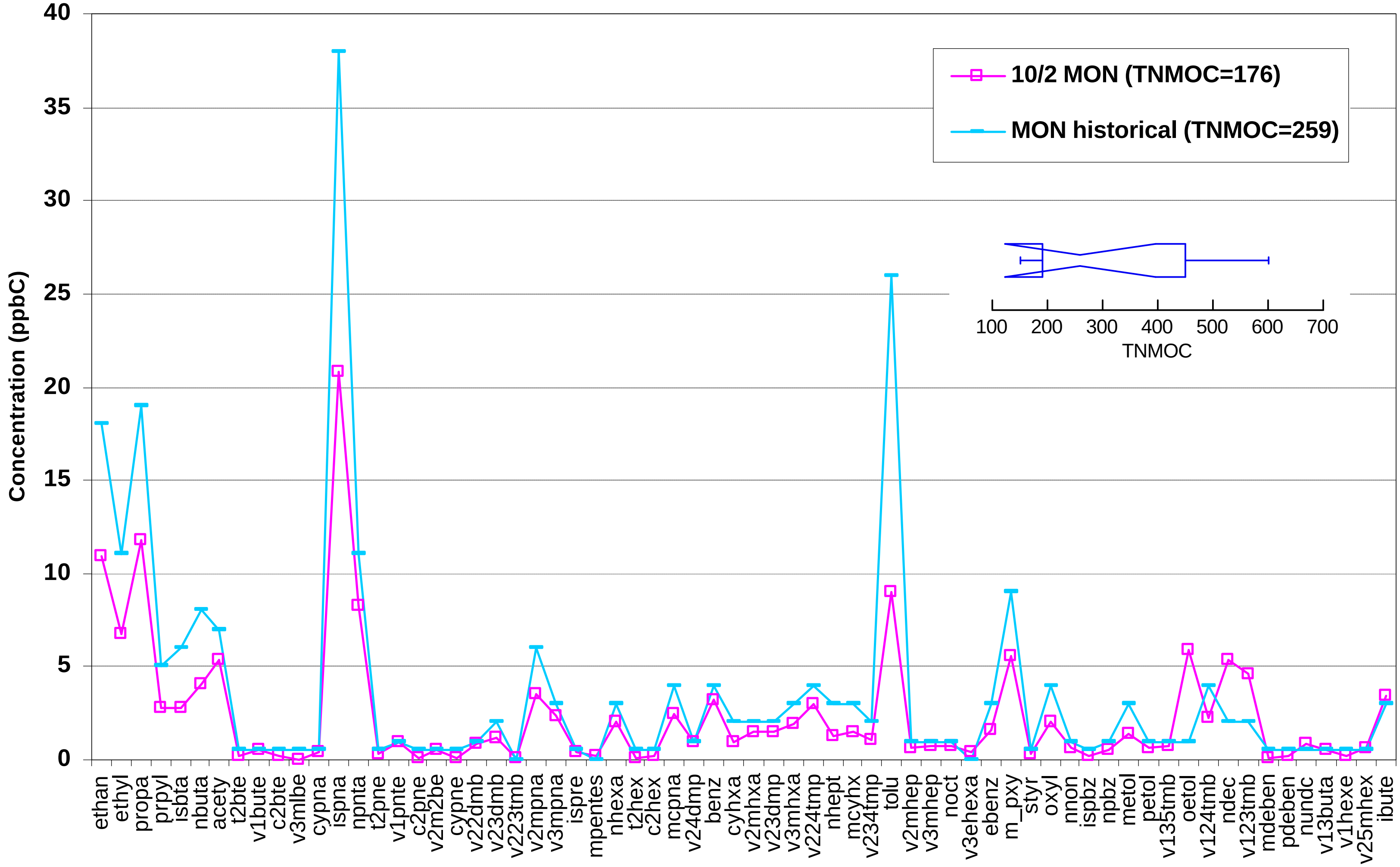

Figure 4-25. Median concentrations (ppbC) of hydrocarbons at Los Angeles N. Main at 0500 PST during the special study period compared to historical data (Mondays). A notched box-whisker plot of historical TNMOC concentrations (ppbC) at 0500 PST is also provided. Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

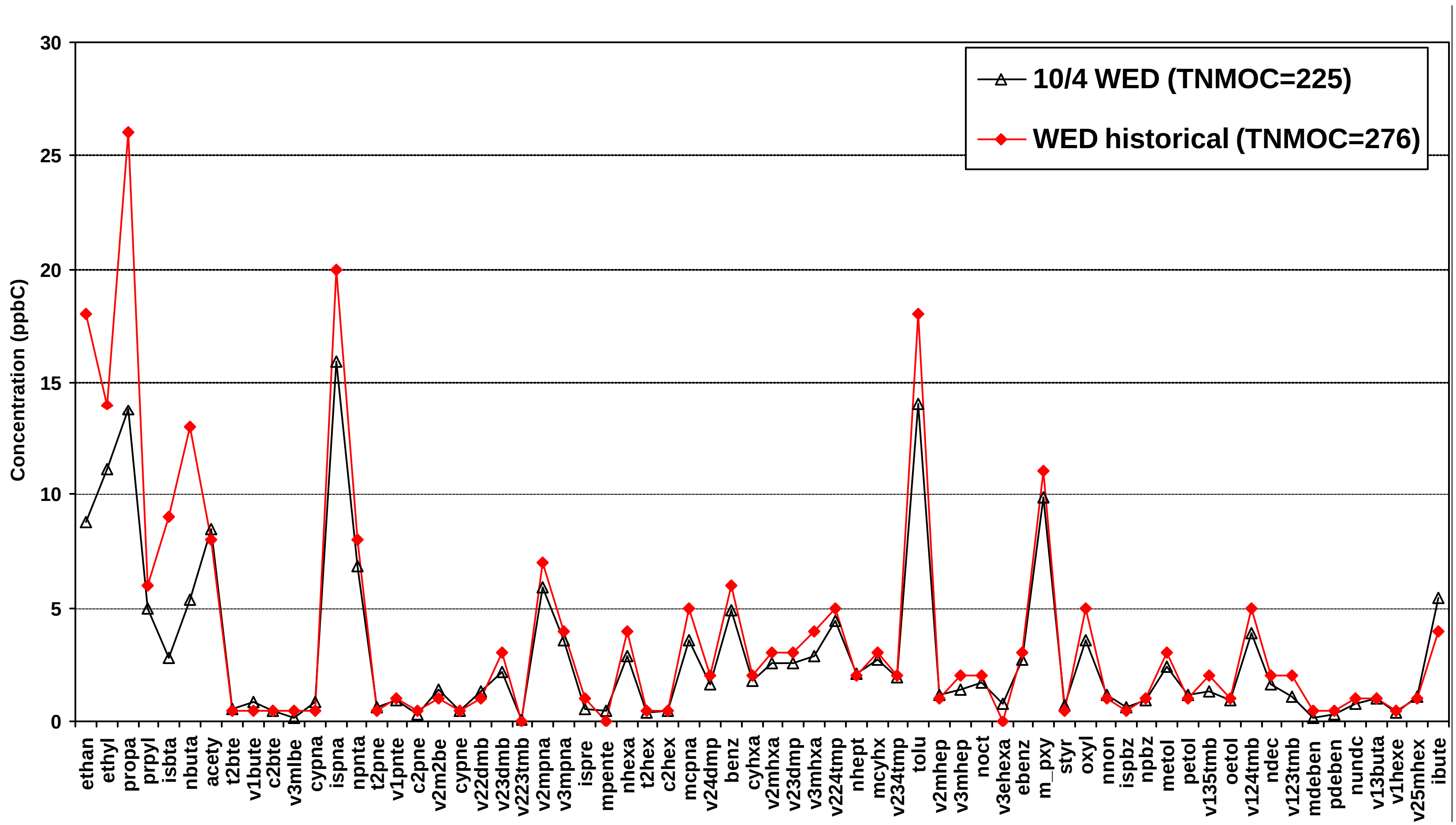

Figure 4-26. Concentrations (ppbC) of hydrocarbons at Los Angeles N. Main at 0500 PST during the special study period compared to historical data (Wednesdays). A notched box-whisker plot of historical TNMOC concentrations (ppbC) at 0500 PST is also provided. Species abbreviations are provided in Appendix J. The "V" in front of the abbreviation signifies "variable" and is added by the SYSTAT software.

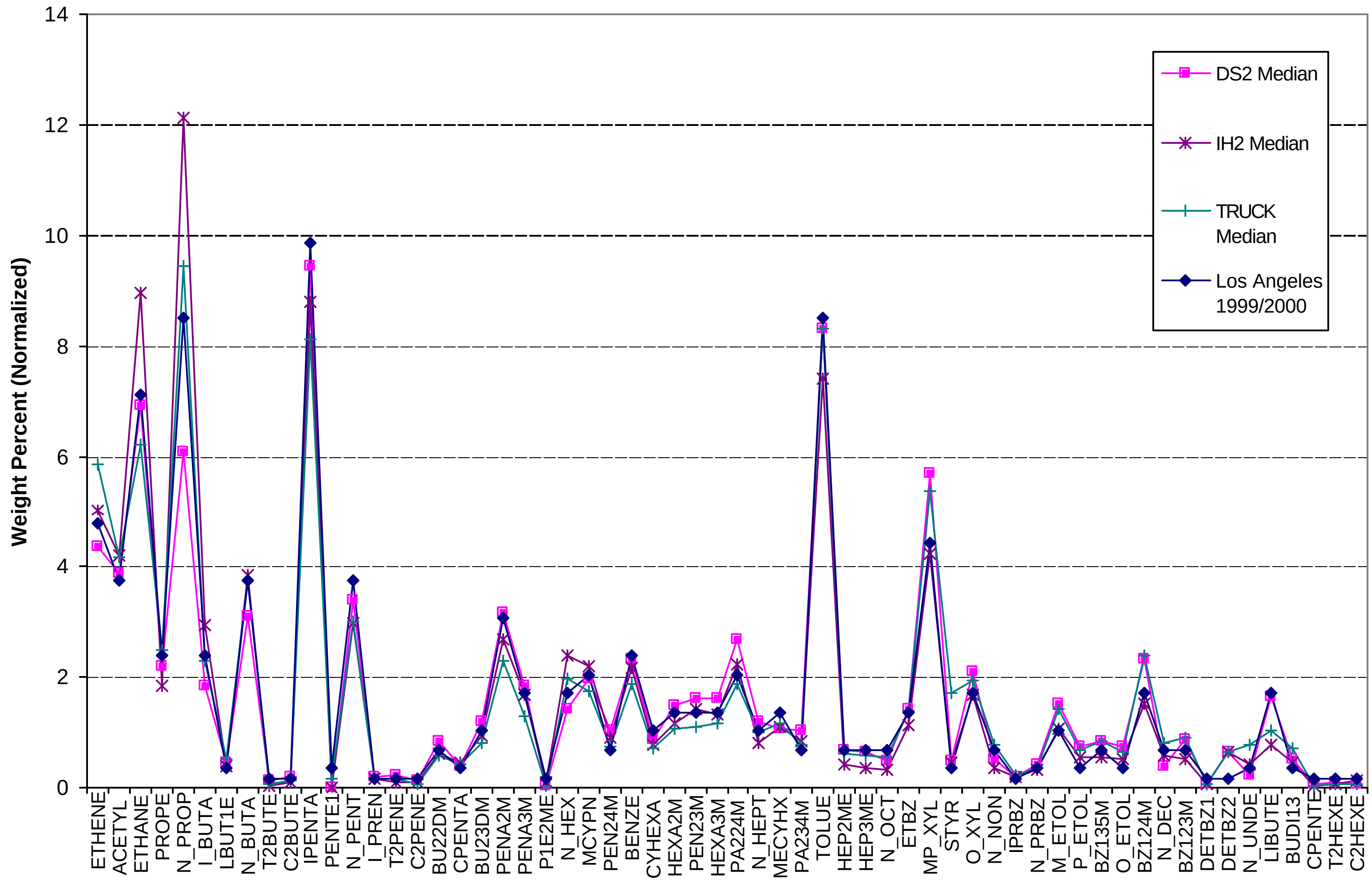

Figure 4-27. Normalized weight percent of hydrocarbons at Los Angeles N. Main at 0500 PST compared to the median of the DRI mobile van samples collected during the special study at Dodger Stadium (DS2), Industry Hills (IH2), and at the truck stop (TRUCK). Species abbreviations are provided in Appendix J.

Wednesday, October 4, and Saturday, October 7

- Concentrations of most species were higher on Wednesday than on Saturday at 0500 PST (Figure 4-28). Exceptions were ethane and n-butane. The weight percent plot further emphasizes the differences in the C2-C4 species. On a reactivity-weighted basis, the Wednesday sample was potentially more reactive than the Saturday sample, particularly noting the ethene, propene, and aromatic hydrocarbons (Figure 4-29).
- Concentrations of all species were higher on Wednesday than Saturday at 0800 PST; however, the weight percent of the species were nearly identical (Figure 4-30). Small differences were noted in propane, n-hexane, xylenes, and toluene (higher on Wednesday) and ethane and i-pentane (higher on Saturday).

Monday, October 2, and Sunday, October 8

- Concentrations of all species except propane were higher on Sunday than on Monday at 0100 PST. The composition of the two samples was the same with the exceptions of ethane, propane, and the butanes (higher on Monday).
- At 0500 PST, concentrations of the hydrocarbons were still higher on Sunday than on Monday with the exception of o-ethyltoluene, n-decane, and 1,2,3-trimethylbenzene. On a weight percent basis, the fractions of propane and the pentanes were also higher on Monday.
- By 0800 PST, concentrations of most hydrocarbons were higher on Sunday than on Monday, with extremely high concentrations of the pentanes (>50 ppbC) observed on Sunday. The high pentanes may indicate a nearby spill of gasoline.

Mobile Van Samples

We inspected the fingerprints of the canister and Tenax samples collected in the mobile van by DRI during the field study. DRI reports many more species than those reported as part of the PAMS program (see Appendix J). We loosely arranged the samples into seven groups, took the median of each group, and plotted the resulting fingerprints on two plots in order to show the data (**Figures 4-31 and 4-32**). The groups were Covina Loop (CL2 in the plot), Compton Loop (CO2), Dodger Stadium (DS2), gasoline exhaust (GP), Industry Hills (IH2), miscellaneous (MISC), and truck stop (Truck). The highest median concentrations were observed for most species on the Compton Loop route. The lowest median concentrations were observed at the Industry Hills site. The truck stop samples have the highest median concentrations of several species including limonene, methylene chloride, 2,4-dimethylheptane, C10 aromatic, and dodecane, tridecane, tetradecane, and other higher carbon number alkanes. Additional analysis of the day of week differences in speciation will be performed as a part of the integrated report.

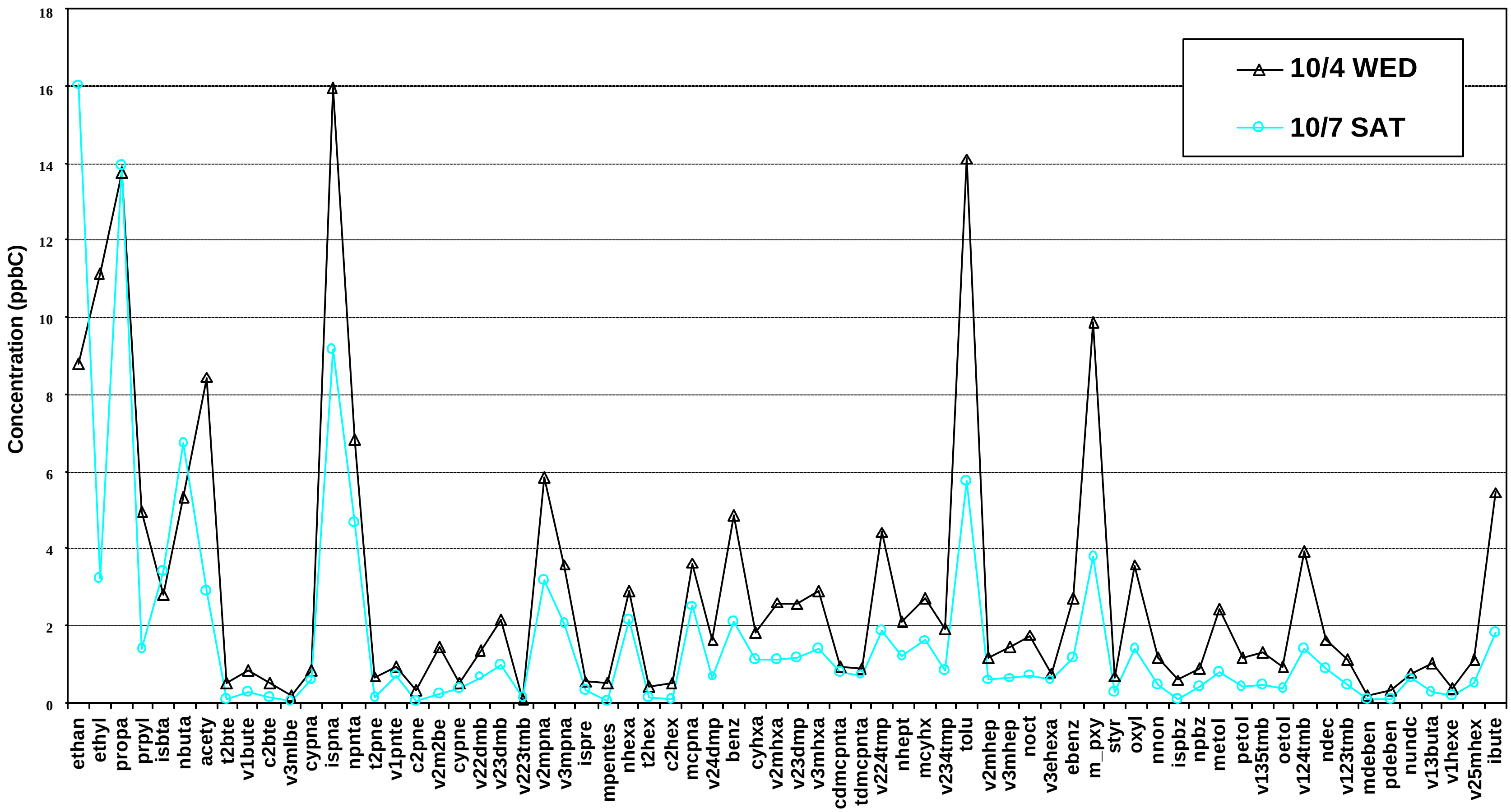

Figure 4-28. Concentrations (ppbC) of hydrocarbons at Los Angeles N. Main at 0500 PST on October 4 and 7, 2000. Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

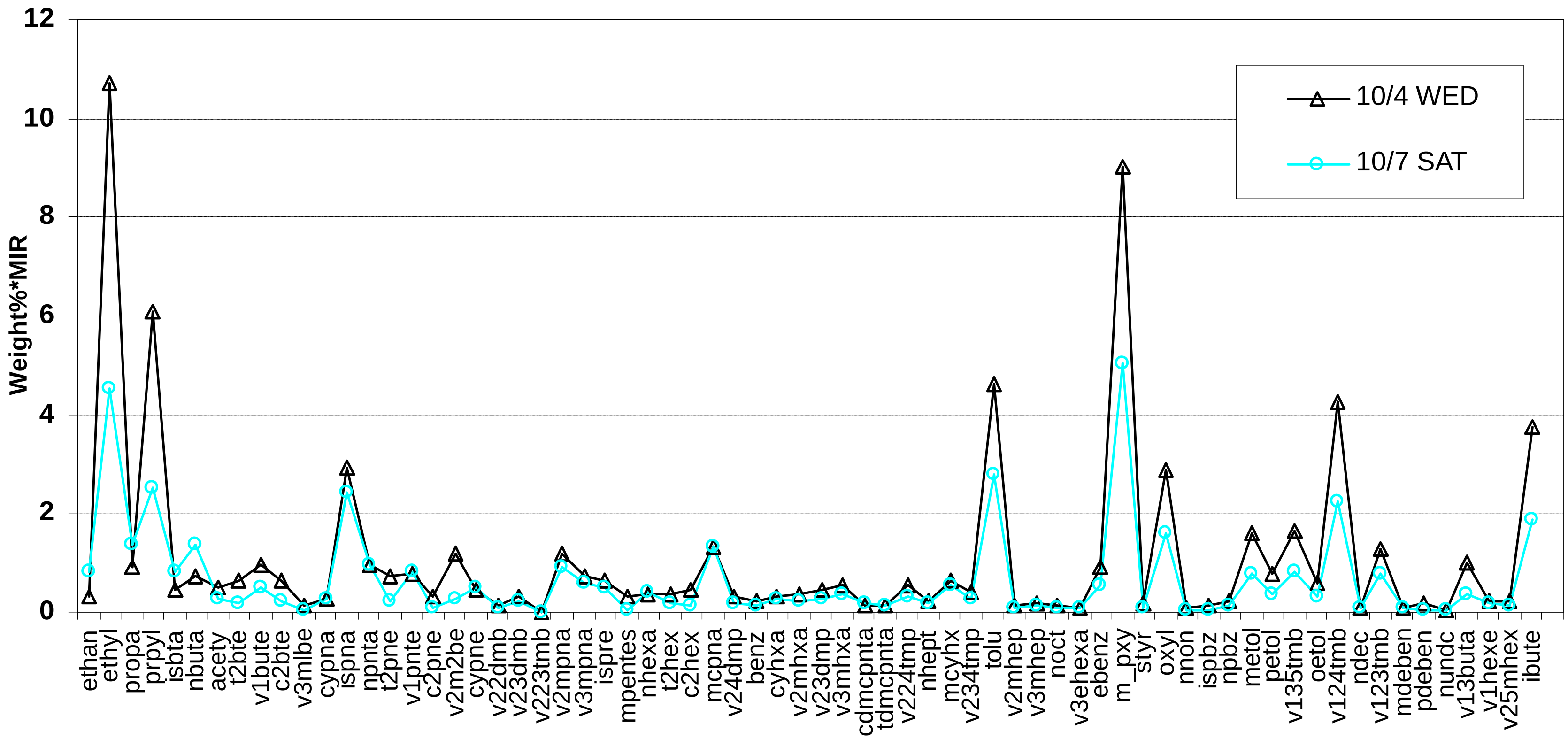

Figure 4-29. Reactivity-weighted composition of samples collected at Los Angeles N. Main at 0500 PST on October 4 and 7, 2000. Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

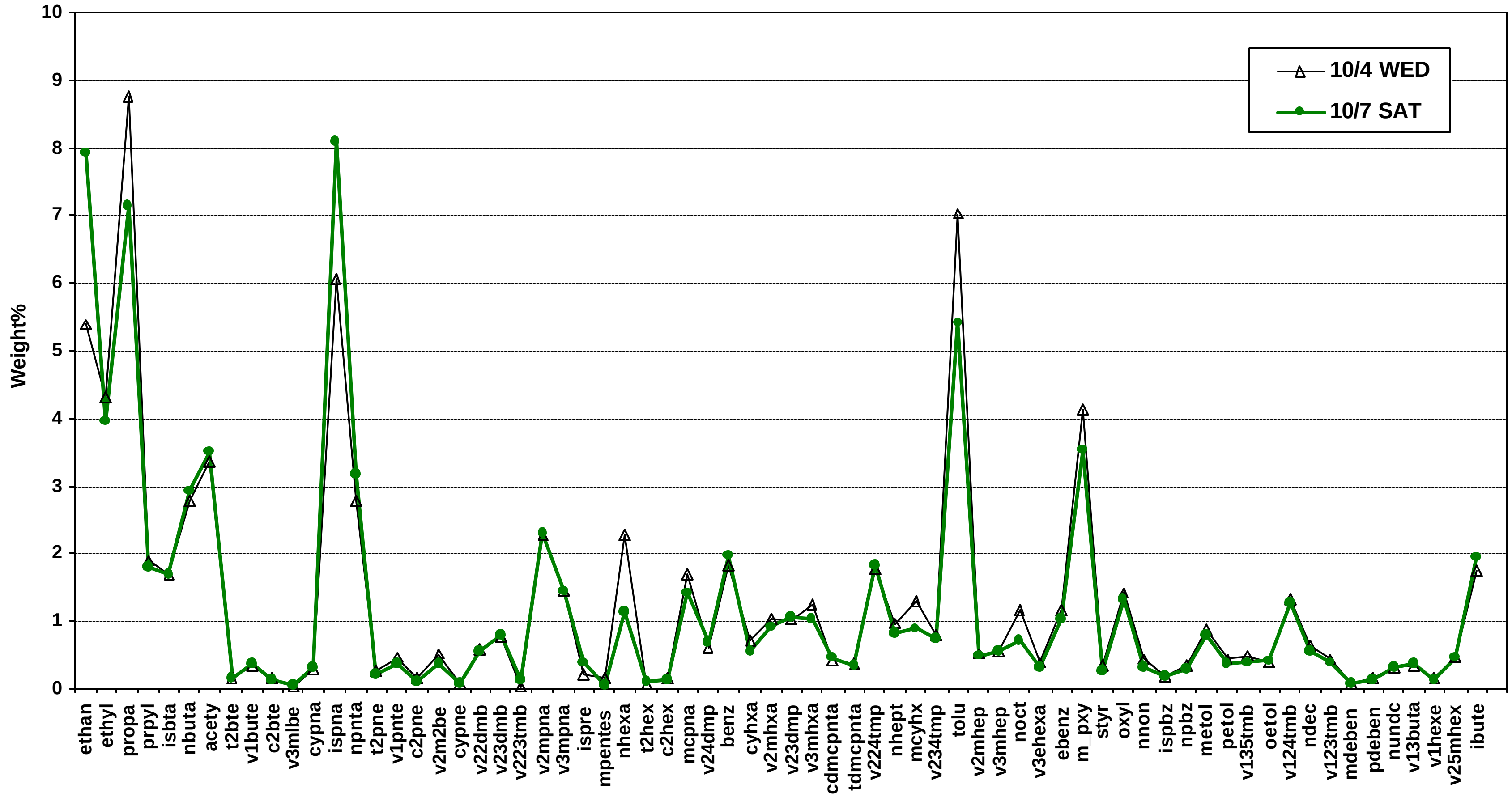

Figure 4-30. Weight percent of hydrocarbons collected at Los Angeles N. Main at 0800 PST on October 4 and 7, 2000. Species abbreviations are provided in Appendix J. The “V” in front of the abbreviation signifies “variable” and is added by the SYSTAT software.

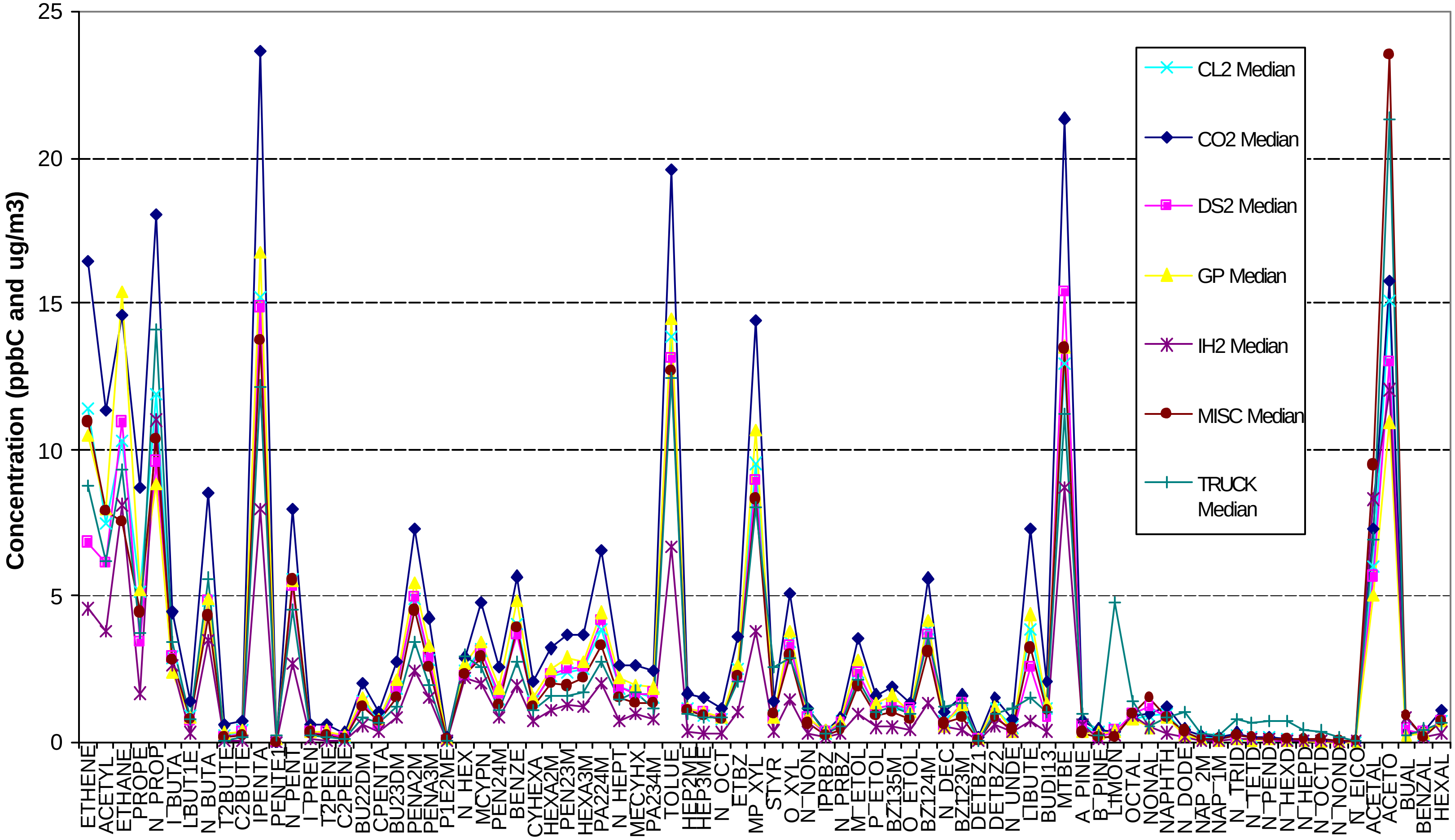

Figure 4-31. Median concentrations (ppbC and μg/m^3) of species collected by DRI in the mobile van during the special study in October 2000. Species abbreviations are provided in Appendix J.

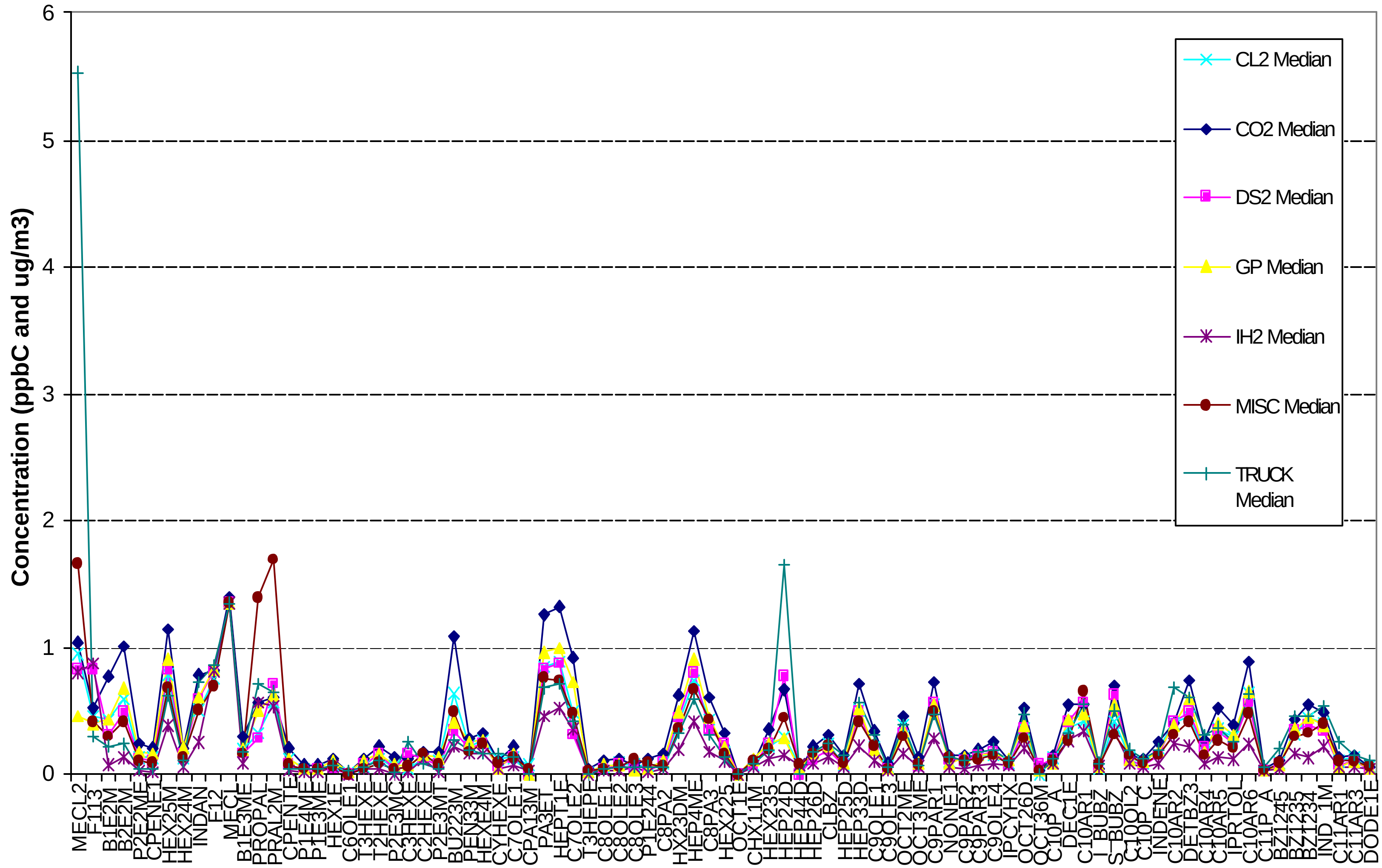

Figure 4-32. Median concentrations (ppbC and µg/m^3) of species collected by DRI in the mobile van during the special study in October 2000. Species abbreviations are provided in Appendix J.

4.4 SUMMARY AND IMPLICATIONS

The following conclusions may be made from the investigations in this section:

- At Azusa and Upland, many of the PAMS hydrocarbons exhibited statistically significant lower concentrations on Sundays overall than on weekdays. This finding is consistent with reduced motor vehicle activity on Sundays. Most hydrocarbon concentrations were similar from day to day at sites closer to the urban core, such as Burbank, Los Angeles N. Main, and Pico Rivera. Species concentrations were also often lower on Saturdays than on Fridays but comparable to concentrations on Mondays and Tuesdays.
- The weight percent, or composition, of the hydrocarbons did not appear to show a statistically significant day-of-week change, indicating the source of these species did not change with day of week.
- Most of the samples collected at Los Angeles N. Main by CARB during the special study period (September 30 through October 8, 2000) had concentrations and compositions within the interquartile range of data collected during 1999 and 2000. Significant differences between the special studies data and historical interquartile ranges at 0500 PST were noted as follows:
  - October 7, 2000 – lower concentrations
  - September 30, 2000 – higher concentrations and higher weight fractions of C2-C4 hydrocarbons
  - October 1 and 8, 2000 – higher concentrations; however the composition of both samples were very similar to historical data
- In one pair of the special studies data, the day-of-week differences were consistent with day-of-week differences in the historical data. For example, concentrations were generally higher on Wednesday than on Saturday at 0500 PST (October 4 and 7, 2000) except for higher fractions of less-reactive ethane and butane on Saturday.
- In the October 2 and 8 pairing, the Sunday samples exhibited higher concentrations than historical interquartile ranges (although the composition was consistent with historical data). The samples collected on October 8 had unusually high concentrations and do not appear representative of typical weekends.

DRI mobile van samples collected near Dodger Stadium had composition very similar to the CARB samples collected at Los Angeles N. Main (for matching species).

5. CONCLUSIONS

This report describes the results from the analysis of the weekday and weekend emission activity data and the analysis of air quality and meteorological data on the days of the summer/fall 2000 field study. Conclusions from the analysis of emission activity data, analysis of meteorological data, and comparisons of field study air quality data with historical data are presented in this section.

5.1 EMISSIONS ACTIVITY

Observations of daily activities and common sense suggest that aggregate variations in human activities, which follow a weekend-weekday pattern, cause observable differences in weekend-weekday air quality, specifically ozone precursor emissions, and therefore, ambient ozone levels. The principal emphasis of STI's investigation of possible causes of the weekend ozone effect was on emissions activity data collection and analysis. In Phase II of this effort, we collected activity data for several emission source categories and subcategories. In this report, we have summarized the data collection efforts and analyzed the resulting activity data to obtain real-world estimates of the activity variations by day of week for major emission source categories in the SoCAB. We made the following observations:

- Combining emission changes for all categories (including off-road categories) by day of week results in an estimate that total 2000 ROG and NOx emissions in the SoCAB on weekends in the summer decline by about 12 to 18% and 35 to 41%, on Saturdays and Sundays, respectively, relative to weekdays. These changes in emissions result in an increase of the ROG to NO_x ratio of more than 30% on weekends.

These overall observations are supported by the following conclusions:

- A survey of business activity showed that business activity declined substantially on weekends (by up to 80%).
- A survey of residential activity showed that some residential activity increased substantially on weekends.
- In the urban areas of the SoCAB, surface street traffic volumes (which were dominated by light-duty vehicles) showed that traffic was reduced by about 15-30% on weekends and tended to peak around midday rather than during the morning and afternoon rush hours as on weekdays.
- Freeway traffic volume information showed that truck and bus activities decreased by up to 80%. On weekends in areas just beyond the urban zones, daily traffic volumes increased somewhat on weekends and tended to peak on Friday and Sunday late afternoons.
- Major point source NO_x emissions on Friday, Saturday, and Sunday were 8-18% lower, on average, than on Monday through Thursday. Note: if point source ROG reductions

on weekends are proportional to NO_x reductions[6] (not proven in this study), day-of-week variations in point source ROG emissions could also play a significant role in the weekend ozone effect since point source emissions comprise 20% of ROG emissions.

- In year 2000, the single largest contributor to emission changes on the weekends is a substantial decline in heavy-duty truck traffic (representing 25% of all NO_x emissions on weekdays and 12 to 15% of all NO_x emissions on weekends).
- ROG emissions from recreational boats on Sunday are higher than from automobiles (see Appendices H and I). This does not seem likely. Because the weekday/weekend activity data for recreational boats appears reasonable, we believe the summer 2000 ROG inventory for recreational boats may be too high and recommend further study of this issue.
- Weekday/weekend off-road emissions were modeled using Lawn and Garden and Business IC Engine activity data. These 2000 ROG and NO_x emissions in the summer decline on weekends by 41 to 64% and 72 to 78% on Saturdays and Sundays, respectively, relative to weekdays. Note that day-of-week patterns of off-road engine use, other than lawn and garden equipment, are uncertain because the limited data collected during the business portion of the survey may not represent the proper distribution of off-road IC engines.
- Although projecting emission inventories into the future is quite uncertain, application of day-of-week patterns to future-year published emission inventories suggests that because of predicted increases of the HC/NO_x ratio in emissions, ozone concentrations in the future may not decline despite predicted decreases in emissions.

5.2 METEOROLOGICAL EFFECTS

Although weather conditions during the 2000 field study period were generally not favorable for high ozone and ozone precursor concentrations, this did not affect study results because the study was emissions-based. The highest ozone day in the study period was Sunday, October 1. Nevertheless, qualitative analyses of day-to-day variations in meteorological conditions showed that each weekend day had a reasonably similar meteorological weekday companion. From a meteorological standpoint the best dates for comparison are

- Saturday, September 30, 2000, and Thursday, October 5, 2000
- Sunday, October 1, 2000, and Monday, October 2, 2000
- Saturday, October 7, 2000, and Wednesday, October 4, 2000
- Sunday, October 8, 2000, and Monday, October 9, 2000

Although not precisely the same, the days with similar meteorology provide an opportunity to minimize the influence of meteorology on day-to-day variations in emissions activity and ozone precursor concentrations in modeling.

[6] ROG and NO_x are not always produced by the same industrial processes.

5.3 AMBIENT HYDROCARBON CONCENTRATIONS AND COMPOSITION

Hydrocarbons are important precursors to ozone. By understanding their temporal and spatial characteristics, one can gain insight into likely hydrocarbon emission sources. We investigated the available historical hydrocarbon data and the data collected during the September-October 2000 field study. The investigations were focused on the following questions, which were designed to address the weekend ozone effect. Findings are provided with each set of questions.

1. *Have historical hydrocarbon data collected in the SoCAB indicated a pattern by day of week? What are day-of-week trends in speciation (concentration, weight percent, and reactivity-weighting) at these sites? Are these trends statistically significant?*

   - At Azusa and Upland, many of the hydrocarbons exhibit statistically significant lower concentrations on Sundays overall than on weekdays. This is consistent with reduced hydrocarbon emissions-related activities on Sundays. Species concentrations are also often lower on Saturdays than on Fridays but comparable to concentrations on Mondays and Tuesdays. Most hydrocarbon concentrations were independent of day of week at sites closer to the urban core, such as Burbank, Los Angeles N. Main, and Pico Rivera.
   - The weight percent, or composition, of the hydrocarbons does not appear to show a statistically significant change by day of week, indicating the source of these species does not change by day of week.

2. *How did the special studies data collected by the CARB at Los Angeles N. Main during October 2000 compare with data collected in previous years at the same site? How did special study canister samples collected by DRI at Dodger Stadium near Los Angeles N. Main compare to speciation at the PAMS site?*

   - Most of the samples collected at Los Angeles N. Main by CARB during the special study period (September 30 through October 8, 2000) had concentrations and compositions within the interquartile range (25^{th} to 75^{th} percentile) of data collected during 1999 and 2000. However, there were significant differences between the special studies data and historical interquartile ranges for a few 0500 PST samples as follows:
     - October 7–lower concentrations, but composition was similar
     - September 30–higher concentrations and higher weight fractions of C2-C4 hydrocarbons
     - October 1 and 8–higher concentrations; however the composition of both samples were very similar to historical data
   - DRI mobile van samples collected near Dodger Stadium had compositions very similar to the CARB samples collected at Los Angeles N. Main.

3. *Were there day-of-week differences in speciation during the field study?*

    - In one of the special studies data weekday/weekend pairs, the day-of-week differences were consistent with day-of-week differences in the historical data. For example, concentrations were generally higher on Wednesday than on Saturday at 0500 PST (October 4 and 7, 2000).

The samples collected on October 8 had unusually high concentrations and do not appear representative of typical weekends.

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